Curved Eave House on Private Estate

AMERICAN GREENHOUSE CONSTRUCTION

HEATING AND EQUIPMENT

By
RICHARD T. MULLER
Assistant Professor of Floriculture
Massachusetts Agricultural College

NEW YORK
A. T. DE LA MARE COMPANY, INC.
1927

FOREWORD

MUCH in the way of improvement of florist crops in recent years, has been the result of the rapid advances which have been made in greenhouse construction engineering. A good deal of the credit for the advancement of floriculture is due to the zeal of the manufacturers of greenhouse materials who have tried to hold the grower's interest at heart and give them an efficient modern plant factory. It is to these, whose praises usually remain unsung, this book is humbly dedicated.

The writer wishes to acknowledge with thanks the permission to use photographs, line drawings and tables of data which were made available to him through the courtesy of the following companies:

American Greenhouse Manufacturing Co., T. J. Callahan Co., A. Dietsch Co., Foley Greenhouse Manufacturing Co., Hitchings & Co., King Construction Co., Lord & Burnham Co., William H. Lutton Co., Metropolitan Greenhouse Manufacturing Corporation, John C. Moninger Co., A. T. Stearns Lumber Co.

References are further made in the text to special contributions by the Lord & Burnham Co., Hitchings & Co., Mr. James H. Beattie of the U. S. Dept. of Agriculture, and Mr. Frank J. Moreau of the Moreau Plant Co.

RICHARD T. MULLER

Amherst, Mass., November, 1927

PREFACE

THE USE AND VALUE OF A GREENHOUSE AS AGAINST OPEN FIELD PRODUCTION

THAT the growing of plants in a greenhouse has decided advantages over open field production is obvious. The growing conditions can be more readily controlled under glass. A more intensive cultural laboratory for plants is provided in which the temperature, water, soil, air, fertilizers, insect pests and diseases may be regulated to a large extent. The amount of sunlight is the only factor at present which cannot be controlled. Even this is being given careful investigation and some progress has been made and good results obtained with artificial illumination.

While open field production is undoubtedly the cheaper, the superior quality of greenhouse crops is unquestionable. The crops to which greenhouses are devoted cannot be grown outdoors at the time except in southern climates. Only in the case of vegetables is this southern competition important, because most of the florist crops are too perishable to permit distant shipping. Nevertheless, greenhouse grown vegetables produced near the markets reach the consumer in a fresh condition, without the delays incident to long shipment, and so are of higher quality.

The growing of flowers and vegetables in greenhouses offers special inducements to those having a liking for the work and sufficient knowledge to enable them to produce high quality products. There always seems to be room enough for another grower in any location provided he grows good quality products.

Nurserymen and seedsmen likewise are finding greenhouses a valuable addition to their equipment, as well as frames. The present day demand for evergreens has brought about the large-scale propagation of these plants in greenhouses and frames. The seedsman at present is ever striving to produce special greenhouse strains of seeds and so also needs glass to accomplish his aims.

In conclusion it might be added that undoubtedly the greatest advantage of greenhouse culture is the fact that flowers and vegetables may be had out of season. Without them we could not have flowers to enjoy during the winter months. Our supply of fresh vegetables would likewise be curtailed and, in addition, many plants could not be had in the spring to set out in the garden large enough to give maximum returns during the summer.

CONTENTS

CHAPTER I

Essentials of a Greenhouse—Light—Heat—Moisture Water—Air—Soil—Location—Making a Start

PREVIOUS to considering the actual construction of greenhouses it is well to discuss briefly a few of the vital factors concerned in the welfare of plants. A consideration of these will enable one to appreciate better the importance of good construction in its relation to healthy plant growth.

As previously stated, cultural conditions are readily controlled in a greenhouse. The principal requirements for plant growth in their relation to greenhouse construction are: *Light*, *heat*, *moisture*, *air* and *soil*. These must be given careful study so that they make this control as nearly perfect as possible.

LIGHT

In order to appreciate the importance of maximum light in a greenhouse we must realize that about 95 per cent of the substances contained in the plant is derived from the atmosphere. Through the action of light on the green matter located principally in the leaves, these substances, combined with water, are manufactured into plant food. This process takes place in the daytime under the influence of light. The foods thus manufactured are used during the night, for contrary to general belief, plants make most growth at night.

Thus it can be seen that maximum light conditions tend toward large food manufacture and a consequent healthy growth. The light assists in the development of supportive tissues which enable the plant to resist attacks of various

diseases. Lack of proper light in greenhouses causes the plants to possess little or no resistance to disease, and this is especially true during the winter months. Roses, tomatoes and cucumbers, for example, require more light during this time than many ordinary houses are able to furnish.

An excess of light such as is experienced during the summer months is also detrimental to plant health in greenhouses and so shading the glass becomes necessary. Furthermore there are numerous conservatory plants such as palms which require less light. Too much light affects the transpiration of these plants and causes them to wilt badly.

Factors which will increase the amount of light in a greenhouse should be encouraged. Among these are: Large glass with small lap; reduction of size and number of the sash bars, purlins, posts to minimum size; solidly framed houses so breakage of glass will be reduced; the proper roof pitch, practical to build and yet allowing a large percentage of light rays through the glass, as well as clear quickly of condensation, snow and ice; location of the houses so they receive the light from morning until night; and large houses so that the shade-casting members are farther from the glass, thus diffusing the shadows cast on the plants.

HEAT

Growers with poorly constructed houses often attempt to substitute heat for light in forcing plants. This results in failure generally, because the plants make soft, succulent growth which is an easy prey to disease and which has poor substance or keeping qualities.

The heat requirement of indoor crops demands close attention and while related to the question of light, cannot be used as a substitute.

It is of course appreciated that a plant requires different temperatures in its various stages of growth and also that no two crops desire the same temperature. In the latter

case, however, good crops may be produced even though two or more crops are being grown in the same house and in the same temperature. Yet the normal temperature requirements for these crops cannot be much more than 3 to 5 degrees apart. The specialist will prefer one crop to a house to produce the highest quality.

The temperature of the soil and that of the air should be nearly the same for best results. Many florists are today replacing ground beds with raised benches to get this condition during the winter months and thus obtain increased winter production. In the ground beds the soil temperature is colder than the greenhouse atmosphere and so the root action is sluggish. The raised benches with warm air beneath them are better..

A greenhouse therefore should be provided with a uniform constant heat, especially during the night, and the house should be tightly built to prevent a greater loss of heat than necessary. Likewise a good distribution of the heating pipes throughout the house must be provided, so that all parts of the house may be heated as nearly as possible to the same temperature.

MOISTURE

In a greenhouse the moisture in the air (humidity) as well as that in the soil is important. Temperature and humidity are inseparable in greenhouse culture and are as important as the food requirements of plants.

As in the case of the temperature, each crop requires different humidity conditions. The rose and the maidenhair fern for instance require a very humid atmosphere, while ornamental cacti thrive best in a dry atmosphere. An increase in temperature will decrease the humidity, and vice versa.

With plants such as the rose where it is desirable to maintain a humidity of at least 75 per cent, the walks

are watered, as well as the plants syringed on all bright days. Walks of cinders or brick are superior to those of cement for this purpose as they absorb the water and help maintain the moisture in the atmosphere longer than in houses with cement walks. In the latter case special evaporating pans may be necessary in order to provide this atmospheric moisture. This is especially true in conservatories.

WATER

Water is essential to plant life. It has been estimated that some crops evaporate from the leaves an amount of water equal to about three hundred times the weight of the dry matter which they contain. It therefore needs no further argument to realize that water, readily available and in unfailing amounts, must be provided for in a greenhouse.

The more water in the soil, the less air it contains and since the roots require air as well as the leaves of the plant, it can be seen that watering to the point of saturation of the soil for any great length of time must be avoided, as the air will then be excluded. This has a relation to greenhouse construction in that the benches or beds must have ample drainage so that excess water may be freely eliminated.

Surface watering is the common method still employed by most practical growers, but it tends to pack the soil, thus excluding the air, especially when done by inexperienced help. Sub-irrigation has given better results experimentally but as yet is not considered a practical proposition. Special benches or beds must be provided with this system.

Overhead irrigation in greenhouses has met with general favor in vegetable houses and to a limited extent by florists. By this method the dry atmosphere in greenhouses can also be quickly overcome.

AIR

Fresh air is as essential to healthy plant growth as it is to human beings. In greenhouses this air is admitted by special ventilators. A judicious manipulation of these is necessary. Improper ventilation encourages many plant diseases. As a rule, plenty of ventilation should be given whenever weather conditions permit it. There is no economy in keeping the ventilators shut in order to save heat, thus creating a stuffy atmosphere and encouraging disease. Thus the lack of ventilation is as harmful as an excess. Drafts and strong currents of air should be avoided.

Greenhouses should be adequately provided with ventilators so that a free circulation of air may be provided in summer and also that ventilators may be opened during the winter when the outside temperature is not below freezing, without producing a chill to the plants.

SOIL

The kind of soil necessary for each crop will vary. Nevertheless a few generalities in this regard may be noted. It must be remembered that greenhouse culture is very intensive in nature. The soil used must therefore be rich in plant food and humus and must also be well drained. Greenhouse space is at a premium and poor soil should not be used, otherwise the ideal cultural environment provided for by a modern greenhouse will not serve to best advantage.

SUITABLE LOCATIONS FOR GREENHOUSES

The principal factors which influence the location of a greenhouse or greenhouse range are, the market, transportation facilities, real estate values, soil, climate, water and labor supply. These, with a few lesser considerations, will now be briefly discussed.

The kind of market will influence the location of an establishment. If products are to be sold at retail from the

range, the location would naturally be near the city or town, on a principal road. A location between the city limits and the beginning of its suburbs would be ideal. Of course a large range of glass could not be economically located here where the real estate value is very high. Nevertheless, a good show room, store and a few houses would suffice, the land perhaps being no larger than 150x100 feet. If more glass would be required later, this could be built further out in the country where the land is cheaper. However, it is always wise to purchase land which has a good future real estate value.

If the products produced at the range are to be marketed chiefly on the wholesale market or if the greenhouses are to supply a retail store in town, a location well out in the country is desirable. Here the land would be cheaper and growing conditions would be much better, less smoke and shade-producing objects being present. Enough land should then be purchased, at least ten acres. The supply of soil would thus be taken care of for a long time.

Of course such factors as good roads and good shipping facilities are important. In the latter case supplies, such as coal would be cheaper, as they can be transported quicker and more economically. A spur track might eventually be run up to the range.

For the wholesale grower, and particularly the specialist, the kind of soil is important. If a suitable location can be found which will yield naturally the kind of soil best suited to a particular crop, the latter can be more economically produced and higher quality result. This is not so serious a factor for the retail grower but nevertheless good soil would be money saved.

The climate in a given locality must be considered as well before locating. Only an unusual market demand would offset very severe climatic conditions. The retail grower would not be so concerned regarding this point as

would be the rose specialist or general wholesale grower. The amount of sunshine in a given locality during winter is especially important to the rose grower.

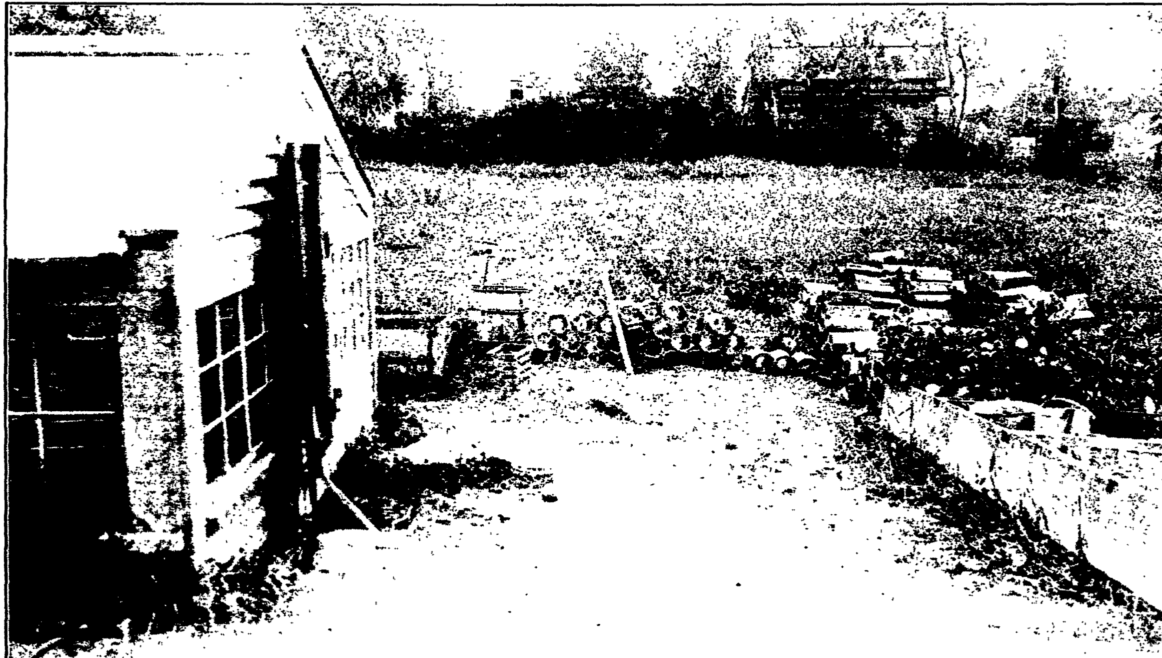
An unfailing water supply must be available. If one can be located so as to use the regular city water supply it will be found a great convenience and saving. Otherwise, a local source such as a nearby pond, stream or well must be utilized.

Finally, the labor supply must be reckoned with, especially with the wholesaler. He must depend on a limitless supply of labor, a good deal of it, cheap, common labor. For this reason establishment near a town which could supply such labor would be desirable.

The retail grower finds himself favorably located as regards the labor supply, because of his direct communication with the city or town. However, he is forced to compete with city wages for his labor and so usually must pay more for help.

In addition to these considerations it is a decided advantage to be familiar with that part of the country in which one wishes to locate. To know thoroughly the local conditions, the kind of people, the character of the community, etc., is of great value. Social conditions must be favorable in order to make it worth while to do business.

The preceding are major factors to be considered in selecting a location for a greenhouse range. A few local factors must be studied after the general location has been selected, which would include the topography or lay of the land and drainage and exposure. Land with a gentle slope to the south or southeast is ideal. Drainage should be good then, and good light conditions would prevail. Land which is very steep would necessitate the erection of sidehill houses and the labor involved in managing these might prove too great. Greenhouses at the bottom of a hill often suffer from poor drainage and poor air circulation.



THIS CRUDE CUMBERSOME GREENHOUSE TOGETHER WITH HOTBEDS WAS THE BEGINNING OF A FLORIST'S PROSPEROUS BUSINESS

A natural protection from the cold north winds, in the form of trees, will aid greatly in protecting the houses from wind damage as well as conserve heat.

MAKING A START WITH GREENHOUSES

Many have started in the greenhouse business in a modest way, possessing not much more than the love of growing plants. There are many cases on record where a person first became interested in growing crops under glass by having a few hotbeds and then later erecting a small greenhouse. This was usually carried on as a side line to regular employment somewhere else, the woman of the house often assisting. The growing of summer crops helped also. Then as this start became definitely established and a certain amount of experience was obtained, more houses were erected and finally full time was put into the enterprise. The earnings at the beginning were reinvested in equipment until there was enough to present a self-supporting plant factory. This may still be a wise way of making a début into the greenhouse business, especially if one is handicapped for lack of capital. It is of course a slow method of procedure but has the advantages in that one can feel his way as to the possibilities of the business in his locality. Also, one can test himself as to his adaptability to the business without having a great deal to lose should the venture fail for one reason or another.

Another way to start in the greenhouse profession is to buy a small range already established. This would require more capital, but as a certain amount of business is already assured, returns could be estimated. The greenhouses bought may not be all to be wished for, but more glass is thus obtained for the money and it will be producing immediately, and new and better houses can be constructed from the money made on the old ones. Needless to say, carefully investigate before buying.

The modern tendency is toward big business and large-scale production. This has also affected the greenhouse industry so that corporations and partnerships are formed with a large working capital and immense ranges may be built at the start. Usually such ranges are devoted to the growing of one or two crops for wholesale. It is beyond the scope of most beginners to enter the business on such a scale. But there is ample room in this broad country for the men with push and energy who start in a small way.

CHAPTER II

Structural Materials for Greenhouses—Wood—Concrete Iron—Stone and Brick—Miscellaneous Hardware

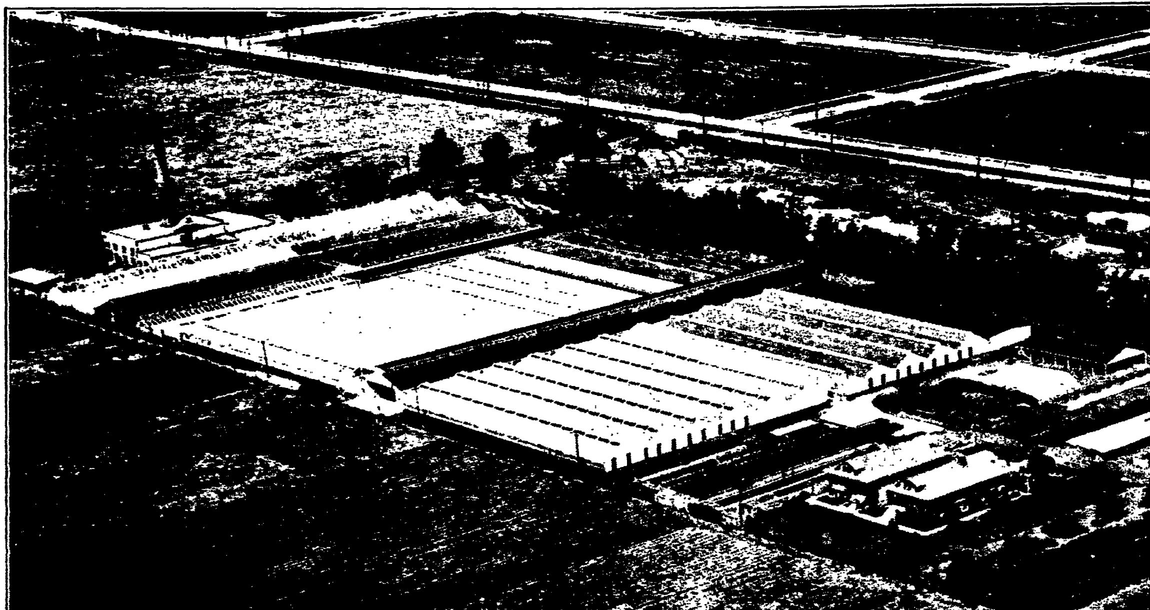
WOOD

WOOD for greenhouses must be durable, not readily subject to decay, must be finely and straight grained, contain no knots or other defects, and must be reasonably light. In a log of wood, the zone next to the bark, from one to three inches or more wide, is of light yellow and is called sapwood. This consists of live cells filled with plant ood; because of this food, sapwood lumber is readily attacked by fungi, causing decay and should not be used.

The inner, darker part of the log is called heartwood. This is made up of dead cells, the walls of which are infiltrated with chemical substances. This substance gives the brown or red-brown color to the wood. The heartwood serves merely the mechanical function of keeping the tree from falling. From this heartwood the most durable lumber is made, and only heartwood lumber should be used in greenhouse construction.

Lumber is usually dried in two ways: naturally, by air, and artificially, in a kiln. The air-dried lumber is best for greenhouses as the kiln-dried generally absorbs from 8 to 10 per cent of moisture from the air after coming from the kiln and in swelling would break glass, etc., while the air-dried has already absorbed its normal amount.

The two best woods for greenhouse construction are Bald Cypress of Louisiana and Florida and California Redwood; the majority of the builders use cypress only. Clear red gulf tank grade cypress is most commonly recommended



FRANK OECHSLIN'S POT PLANT ESTABLISHMENT, CICERO, ILL.

This represents a typical wholesale grower location near a large city (Chicago) but out in the country where land and climatic conditions are favorable. This ridge and furrow range is heated by oil. Note centrally located long potting shed

for the superstructure. This should be air-seasoned in the pile two years before milling. This tank grade cypress is the pure heartwood from the center of the log. Next to the tank grade, No. 1 and No. 2 grades are manufactured and these contain some sapwood. Any grade other than tank grade, will decay quite rapidly.

About 25 to 30 per cent of the cypress trees contain a heartwood which is "pecky." This gives the wood a general worm-eaten appearance and leads to the impression that the injury is due to wood-boring insects. It is however caused by a fungous disease. Since the pecky wood has been found to be practically as durable as the normal, unaffected wood, it is used for rough lumber and is cheaper than normal heartwood. This pecky cypress is generally recommended for the construction of commercial greenhouse benches, and coldframes or hotbeds. In higher grade construction, such as in conservatories and on private estates, the No. 1 grade of cypress, smoothly milled, is often used for this purpose.

When California redwood is used, nothing but clear air-dried heartwood grade is recommended. Redwood is as durable as cypress but as yet has not been sufficiently tested for greenhouse construction. It has been found advisable to use brass screws with redwood, as ordinary galvanized iron screws cause a chemical action when in contact with the wood which causes decay. Redwood is cheaper than cypress.

IRON

The iron of commerce is never pure, but contains varying amounts of other elements such as carbon, silicon, phosphorus, sulphur and manganese. The three chief varieties of iron are cast iron, wrought iron, and steel. Cast iron contains 90 to 95 per cent iron, the remainder being largely carbon with small amounts of phorphorus and sulphur. It is hard and brittle and cannot be welded or forged into

shape, but is easily cast in sand molds. It is strong and rigid but not elastic. It is used for making castings and in the manufacture of other kinds of iron. Malleable iron is cast iron which has been heated and hammered so it will not fracture.

Wrought iron is made by burning out from cast iron most of the carbon, silicon, phosphorus and sulphur which it contains. It is nearly pure iron, usually containing only about 0.3 per cent of other substances, chiefly carbon. It is tough, malleable and fibrous in structure and can be rolled or hammered into shapes.

Steel is made from cast iron, like wrought iron, but usually more carbon remains. A low carbon steel is made by a special process which is used for most structural purposes, for rails and for nearly all large steel articles. It is hard and malleable and is used where great strength is necessary.

It will be seen that wrought iron is very nearly pure iron, while steel contains an appreciable amount of alloy material, chiefly carbon, and cast iron still more of the same substances. In the best construction, therefore, all the posts which come in contact with the damp soil, should be of wrought iron, because of its purity. It does not corrode as readily as steel and has been found to last longer as side posts.

Wrought iron is more expensive than steel, however, and therefore steel, which has been galvanized, is the next best material for posts; if they are embedded in concrete foundation piers which are brought slightly above the grade line, the steel will be exposed above the ground line and thus be protected from this point where the corrosion is greatest.

Heating pipes of wrought iron or cast iron are better than steel because of the smaller amount of rust or corrosion.

Malleable iron fittings are used wherever there is any

stress or strain to be borne, viz., for eave lugs, ridge lugs, column or post tops, miscellaneous truss fittings and supports for heating mains, etc.

Cast iron fittings may be used in such parts as are subject to rust but where little or no strength is required, viz., sill plates, sill lugs, bar sockets, gutters, sash operating and heating fittings.

The cast and malleable iron, while not so pure as wrought iron, can be poured into special molds and so any special or peculiar shapes can be made therefrom, which is not possible with wrought iron or steel. Small and medium sized boilers are made of cast iron.

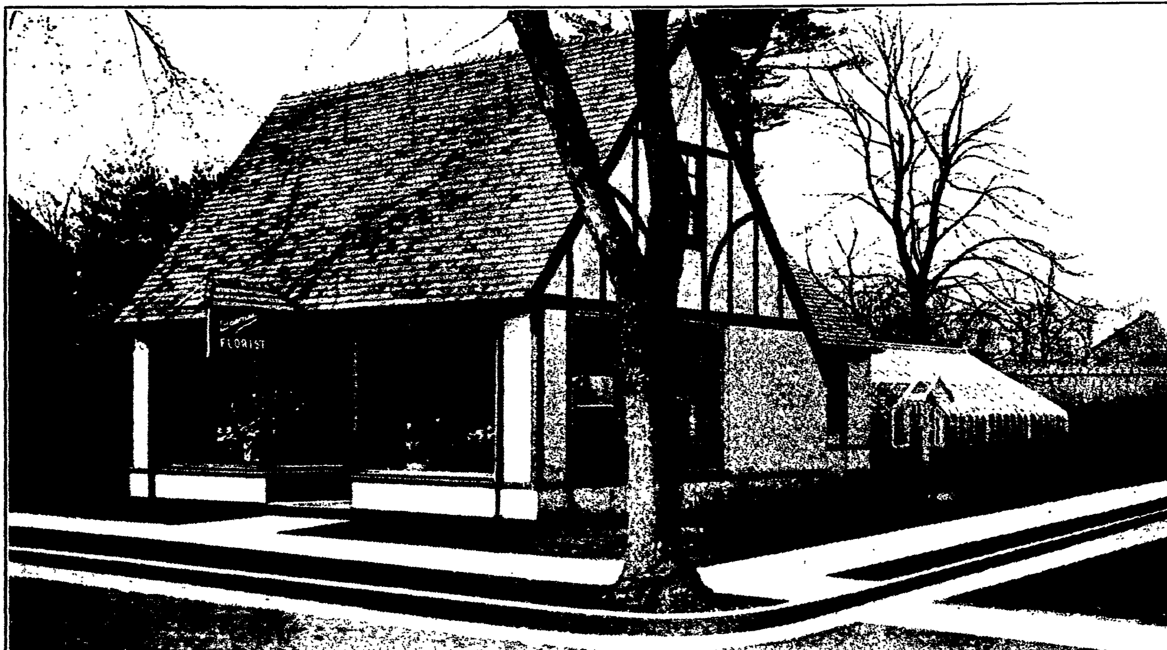
Steel is generally used for all rafters and truss members, roof and gable purlins, eave plates, and for bench frames, where strength is required. Houses over 35 feet wide are more rigidly built of the steel frame type of construction. This steel-frame is composed of flat and angle irons properly spaced and of sufficient size to bear the strain. Any steel used should be of a low carbon content. Galvanized steel is thought by some to be more durable than the ordinary black steel for this purpose. Rerölled steel or any of an inferior quality should not be used. Steel I beams or channel bars are used instead of flat or angle shapes in some heavy types of construction.

Large boilers are made of steel because of its greater strength than cast iron. In order to withstand the pressure the cast iron would have to be so thick as to be impracticable to make.

Because of its cheapness steel is being used more and more to replace cast iron sill plates, gutters and wrought iron eave plates.

CONCRETE

Concrete has almost entirely replaced other materials for the construction of greenhouse foundations and side walls. The amount or thickness and formula vary, depend-



Modern Retail Establishment in Suburbs. Greenhouse in Rear

ing upon where used. The best quality Portland cement or an equivalent brand should be used. If sand and broken stone are used, the sand should be clean and sharp, and the stones should be of 2-inch gauge or smaller. If local sand and gravel mixed are used without screening care should be used to select material free from loam and clay. All concrete should be thoroughly mixed and well tamped into forms. Walls above grade should be given a cement wash on both the inside and outside as soon as the forms are taken down so as to fill the pores and small openings.

If the forms are given a coating of motor oil before the concrete is poured in, they can be removed, leaving a smooth surface of concrete, which will not need a cement wash.

In private construction, the foundation below ground is often made of a solid trench of concrete. This is 12 inches thick, extending 3 feet below the outside finished grade and 8 inches in thickness above grade. These walls are made of concrete consisting of crushed stone or washed gravel. When crushed stone and sand are used, a mixture of 1-2½-5 (1 part cement, 2½ parts sand, 5 parts gravel) is good for the walls below grade. When gravel is used the mixture is 1 to 6, all parts by volume, not weight, the crushed stone being ¾ to 1 inch in size. For walls above grade, usually extending 2½ to 3 feet above concrete, a mixture of 1-2-4 is used, one part cement, two parts sand and four parts ¾ inch crushed stone. If gravel is used for walls above grade a mixture of 1 to 5 is desirable.

In commercial construction, the foundation below grade consists of concrete piers in which are imbedded the sideposts and footpieces. These concrete piers receive the iron posts which support the superstructure and are 12x12 inches or 16x16 inches, according to the size house, and extend 3 feet below grade. These piers are formed of broken stone or gravel concrete 1–2–4 or 1–5 as recommended above. The sidewall above grade is usually 4 inches thick and extends

between the footpieces or sideposts. These walls terminate at a point 4 inches below the inside and outside grade. It is thus called a curtain wall. It is essential to maintain the outside grade at the same level as the inside grade for this type of construction, as the high temperature in the greenhouse counteracts the frost from the outside. Such walls are sometimes built 8 inches thick. They are constructed with cinder, gravel or stone concrete, the cinder concrete however being preferred by many, owing to its lightness and the greater number of voids which tend to insulate against extreme temperature changes. When cinders are used, they must be clean, screened from coal, dust, ashes and other fine matter. The screen should be 3/8 to 1/2 inch mesh, the mixture being one part cement, two parts sand and four parts cinders. The same mixture is also used with crushed stone for aggregate. When gravel and cement are used for these curtain walls the mixture should be 1-5. A mixture of one part cement and five parts cinders has been found satisfactory.

Concrete blocks are good for boiler room construction as well as the concrete mixture. For the floor construction in a boiler room, reinforcements should be used. Woven wire cloth or electrically welded wire cloth, placed continuously over the floor space and supporting beams gives the necessary reinforcement. Rods are frequently used for reinforcing window and door lintels. Practically no reinforcement is necessary in greenhouse walls as the wall acts as a curtain and does not sustain any weight. Occasionally reinforcement is placed at the angle or intersection of two walls, this consisting of bent rods 3/8 to 1/2 inch diameter. The sideposts on commercial houses are tied to the 4-inch curtain wall by means of round iron wall ties, approximately 12 inches long, two being placed to each post.

Concrete for greenhouse walks may be made of the same mixture as that for walls above grade. It should be finished

off with a top finish ¾ inch thick of cement mortar in proportion of one part cement to two parts clean, sharp sand, tinted with lamp black to a dark slate color.

STONE AND BRICK

Stone or brick may be substituted for concrete in greenhouse walls and foundations. Where field stone is available locally in large enough quantity it may be used. Brick may be used where certain effects are desired, as on private estates to match other buildings. The same applies to stone. Usually the expense of brick or stone foundations and walls is double the cost of sheathing or concrete. A stone wall should be 10 to 12 inches thick, and a brick wall 8 inches thick, in order to serve the purpose.

MISCELLANEOUS HARDWARE

The dampness in greenhouses causes very rapid corrosion and deterioration, and therefore such metals as brass, bronze copper and zinc are used where possible. Brass or bronze hinges and brass screws are best but most expensive, therefore the galvanized steel hinges with a fixed or loose brass pin, and brass screws are most commonly used.

Where it is not possible and practical to furnish brass, the hot galvanized screws, bolts and nails should be used, sizes being dependent on where and for what purpose they are used. Generally, 6, 8 and 10d finishing and 18 and 20d common and 16d barbed galvanized nails are used. The only places to use nails in greenhouse construction are in building benches, in putting on double cypress sheathing walls, or for small mouldings. Otherwise, screws should be used.

Lock sets on commercial work are made of cast iron, black japanned mortise locks with cast iron thumb latches. Solid brass or bronze knobs, trim and mortise locks are often used on private work.

For "flashing" work, copper and zinc are best, being used for leaders, drip pans, as well as slip tongues for making watertight joints at the ridge cap and roof bar splices on extremely wide houses. A zinc Z-shaped strip is sometimes used to support the bottom light of glass at the eave. Generally zinc or galvanized wedge-shaped glazing points are employed, in various sizes, the average being ⅝ to ¾ inches.

CHAPTER III

Types of Greenhouses—Forms of Greenhouses—Partitions Foundations and Side Walls—Roof and Gable Supports Roof Pitch—Distance Between Houses—Width and Length of Houses—Roof Bracing

GENERAL TERMS

THE term *greenhouse* originally referred to houses in which plants were kept green or alive over winter. It now includes all glass structures in which plants are grown.

A *forcing house* is one in which plants are grown at high temperatures in order to have them in bloom for a given holiday. Easter lilies, Dutch bulbs and potted rambler roses are examples of plants thus forced. Small, even span or lean-to houses are frequently used for the purpose, these being heavily piped to give the desired temperatures.

A *stove house* derives its name from the fact that originally a brick stove in the house heated it to a high temperature, the house being used for conservatory plants. It is now generally called a *warm house* and of course heated from a boiler in the workhouse.

A *conservatory* or show house is a house in which plants are kept for display, and is generally found on private estates and in public gardens. Commercial men who retail from the range are building show houses to display the plants for sale in a better manner.

A *palm house* is one which is devoted almost entirely to the growing of palms. In order to allow sufficient headroom for the palms, high eaves and ridge are necessary.

A *cold house* is one in which plants are kept dormant or semi-dormant, just above freezing. It is used for storage of plants over winter.

A *propagation house* is one with especially constructed benches and shaded glass, in which young plants are rooted.

FORMS OF GREENHOUSES

Greenhouses may be classified according to the shape and structure of the roof. The points in favor of each type of house may be based upon the amount of light received, economy in heating and the reduced cost of construction.

Several greenhouses together are called a range. This range may be composed of detached houses or attached, the roof of one being attached to that of the next.

The different types of detached houses are: lean-to; uneven span; even span; curvilinear and curved-eave.

Lean-to House

This is the simplest type of greenhouse and consists of a single span of roof built against a wall, the latter acting as one side of the house. This may be built against the south side of a building, on a house built on a hillside or along the north wall of a ¾ span house. In the latter location it makes a good propagating or storage house. It also may be built along the gable ends of a series of houses serving as a connecting house between them and the work house.

A lean-to must be located on the south side and run east and west in order to be a good growing house. Its disadvantage is that it receives light only from one side and flower stems are therefore bent in that direction. Pot plants must be turned around several times to develop symmetrical specimens. Nevertheless, a lean-to is a good house for the beginner, as it is easy to construct and cheap.

Uneven Span Houses—⅔ and ¾

An uneven span house has one long span of the roof facing south, covering ⅔ or ¾ of the width of the house. In some cases it is like an even span house with half cut off the north side. Such houses must also run east and

west for maximum light conditions. Because of this form the two side walls will vary in height on level ground, the north wall being 2 to 3 feet higher. The object of this shaped house is to present the greatest amount of roof glass possible to the rays of sunlight, thus placing the ridge toward the north and having its shade cast on the north wall instead of on the plants.

The original uneven span houses were much used for rose houses, with the benches raised one above the other. On a hillside location, with the latter bench arrangement they are useful, but even span houses have replaced them to a large extent.

Even Span House

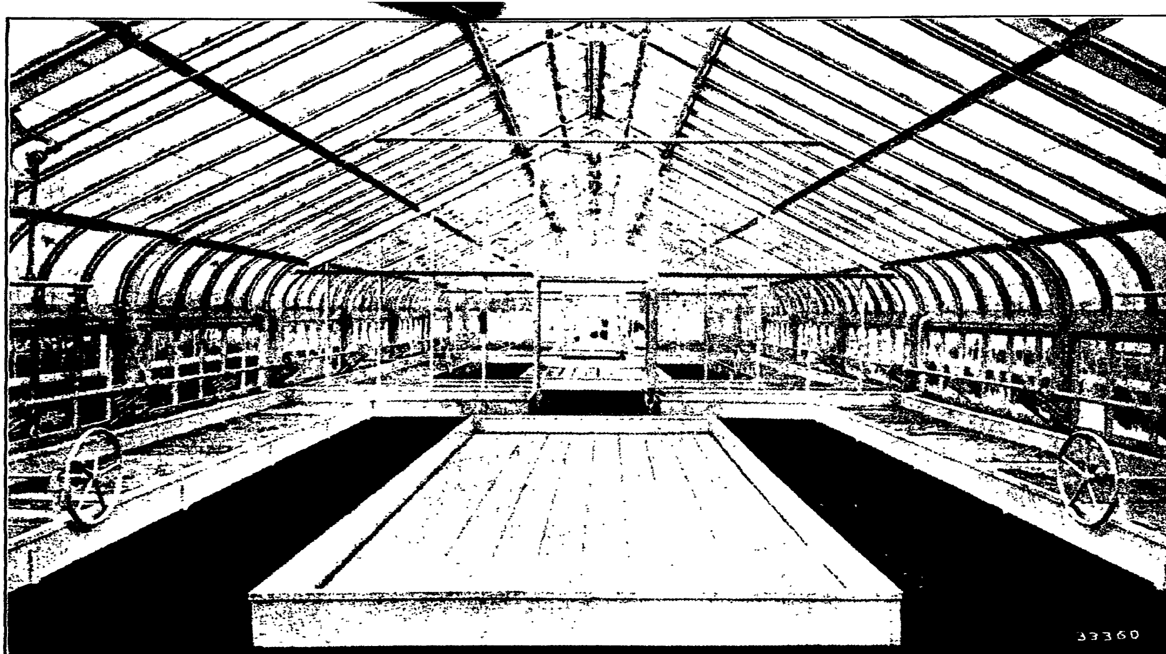
This house may be called a general purpose house. The two sides of the roof are of the same size and both of the same angle. The house can be placed east and west or north and south. It is the style most commonly built today.

Curvilinear House

This type of house has a curved roof and is used more for show and palm houses or conservatories. It is an expensive house because the bars must be curved and curved glass is used, although straight glass in small sizes can be used instead. In the latter case, however, very often a leaky roof results due to the many laps. Usually more ornamentation is added, in the form of a dome or lantern top.

Curved Eave House

The curved eave type is similar to other types except the glazing bars are curved at the eave and curved glass is used at that point. These bars are usually reinforced with galvanized iron so that no eave plate which casts shade need be used. Several types of bars are used. This is also an expensive type of construction and is suitable for private estate houses or a florist's show house (see frontispiece.)



Interior View of Three-Compartment Greenhouse Showing Use of Partitions to Provide Different Growing Temperatures. (For Ground Plan see page 26)

Attached or Ridge and Furrow Houses

Ridge and furrow houses are houses built side by side so that a gutter serves for two sections of the roof. They may be built uneven span running east and west, although generally they are even span. This is cheaper construction than in the case of detached houses for in two houses two side walls are saved. Also, less heat is required for two houses attached than if they were detached as there is less exposure of side wall to the outside temperature. In addition, this type of construction permits economy of space. In regions of heavy snowfall this type of construction is not desirable. If built in such locations steam pipes should be placed under metal gutters to melt the snow as fast as it falls.

Instead of the side walls, posts are used to support the gutters between the houses. Walls may be built if desired, when numerous crops are grown, but they need not be as solid as the outside walls.

These connected houses are good for a number of crops, but when roses are grown it will be found that the flowers have better keeping qualities in detached houses, because the light conditions are better.

Partitions in Houses

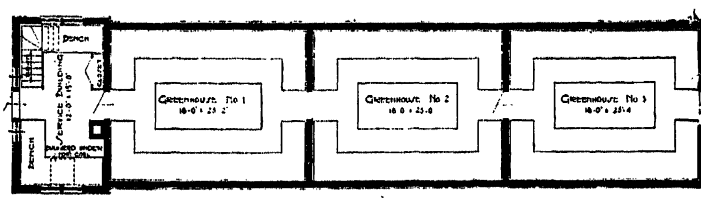
In order to divide a greenhouse into separate compartments, so that crops may be grown in one house under different temperatures, partitions may be built across the house. These can be built of fairly light material as they are not subject to any great stresses and strains.

It should be borne in mind, however, that partitions are an added expense and will cast shade, which of course is not desirable. The growing of the crops in separate houses is better. However, on a private estate and under small operations, partitions dividing the house into separate compartments would be more desirable than to try to

grow a great variety of plants, that require a considerable range of temperature, in an open house at one temperature.

GREENHOUSE FOUNDATIONS AND SIDE WALLS

The side posts in a greenhouse are the true foundations and support the heavy superstructure. These posts, whether of wood, iron pipe, flat wrought iron, or channel iron, should go straight down from the eave plate to 2 or 3 feet deep in the ground below the frost line. The foundation is that mass of stone, brick or concrete which surrounds



Ground plan of three-compartment house. (See page 24)

these posts below ground up to the level of the interior grade of the house. The post holes should be dug about 2 feet square, 3 feet deep and filled with concrete, stone or brick.

The side wall refers to that part of the house from the grade line to the eave. The height of this side wall will vary according to the house width and crop to be grown. In smaller houses up to 25 feet, this height may be 5 feet, while in the larger houses 6 or 7 feet is an average. In a house for sweet peas or cucumbers this height may be increased to 8 feet in order to have enough headroom for the plants toward the side beds. Beyond this height, however, construction is too expensive and only practical for palm houses or conservatories.

An average of 2½ to 3 feet of this height is either boarded up or concreted, the latter being extensively used

Interior View Side Wall

Flat post imbedded in concrete. Side wall not yet built

Interior View Side Wall

8 inch concrete wall. Note drip gutter down spout in operation

today. The remainder of the wall has stationary glass or side glass ventilators or a combination of both.

Double boarded side walls with building paper between and a baseboard and cap may be used for this lower portion of the greenhouse side, but 4 inch concrete walls resting on the concrete foundation piers and being at least 4 inches below grade between posts, are more common today.

A cast iron sill plate is placed on the top of the boarded or concrete wall and thus protects the latter. In a wooden house this sill is made of wood.

At the eave line, the modern angle iron eave plate holds the side ventilators or glazing bars and the roof bars.

Hollow tiles, of concrete or clay, are also used for side walls. These should be plastered on the outside and inside with cement mortar. The tile will have to be cut some and this requires more or less time and ingenuity to use the tile to the best advantage. Thus, concrete is probably the best material.

Pecky cypress boards may be used for the forms and these can later be used for the bottoms of the benches.

The forms for concrete side walls may be made in sections of smooth lumber having the insides covered with used motor oil. A smooth concrete finish will then be obtained when the forms are removed, which needs no cement wash.

Roof and Gable Supports

The roof of a greenhouse must, of course, be properly supported. In order to do this one should know:

1. The weight of the frame itself.
2. How much the wind pressure on that frame when glazed will be.
3. How much the snow pressure of an estimated given amount will be.
4. How and where the pressure will be shifted from one member to another.

5. How much margin should be figured in for a "safety factor" in the allowing of a surplus of strength for extraordinary conditions of snow and wind.
6. The exact weight and strain at any point.

These facts are figured by expert greenhouse engineers and therefore the recommendations in this regard given by the old established greenhouse construction concerns should be relied upon.

In wooden and semi-iron types of construction the roofs are generally supported by interior pipe posts and pipe or angle iron purlins. In the iron frame construction the roofs are supported by iron or steel rafters, angle iron purlins and only a few supporting interior posts or columns. Iron frame houses up to 30 feet wide require no supporting columns; from 35 to 40 feet wide they require two supporting columns; from 55 to 60 feet wide, four supporting columns; and from 65 to 72 feet, four supporting columns. Usually compression trusses are used in houses from 40 feet to 80 feet in width and these can be built with only two columns. Where the arch truss is used, houses up to 60 feet wide can be built without any column supports. However, such a truss without any column supports would be so massive as to make the structure lose its value as a greenhouse. (See diagrams of roof bracing at end of this chapter.)

In some construction the roofs are trussed with light rods depending on a tension basis to a large extent for supporting it. When all members are tight this support may be sufficient but since there is considerable vibration in a greenhouse roof, these rods stretch and the turnbuckles become loose. When one member becomes loose, another does and so it is necessary to go over them occasionally to keep them all tuned up.

The gable end of a greenhouse must be substantially built to withstand the wind pressure it receives almost at

Show House or Flower Shop of Regular Greenhouse Construction

right angles. Near the eave line angle iron or pipe purlins are used across the gable. In addition, pipe braces from the roof purlins are fastened to these, forming a strong brace. In large houses extra heavy posts are used in the gable ends or large pipe posts are fastened in the ground and to the end posts.

Steel sway rods offset terrific wind strains and in large houses should be provided at the gable ends, sides and roofs.

ROOF PITCH

The pitch of the roof refers to the degree of slant or angle formed by the roof line from a horizontal.

Theoretically the roof should be so sloped as to allow the greatest amount of sunlight through the glass on the shortest day of the year, December 20th, when the sun rises only about 25 degrees above the horizon at noon. The sun's rays would have to strike the glass at an angle of 90 degrees to transmit maximum light; to accomplish this the roof pitch would have to be 65 degrees. Such a roof angle would not be feasible as the roof would be too high to be practicable, it would give too great an amount of radiating surface for the amount of ground covered, and would be too expensive to build.

With a roof pitch of 35 degrees, the angle at which the sun strikes the glass is about 55 degrees. We would then have a loss by reflection between 2 to 3 per cent in addition to about 12 per cent loss by absorption, allowing about 84 per cent of the sun's rays to enter the house. This 35 degree pitch is much more practicable than one of 65 degrees as it is less expensive to build and presents less radiating surface through which heat is lost. For this reason the best degree of slant for houses up to 25 feet in width is between 32 degrees and 35 degrees. In wider houses it has been found necessary to reduce this even slightly more to an angle of 26½ degrees, so that the roof may be economically built.

In uneven span houses the roof pitch varies from 26 to 35 degrees in the long span, usually facing the south, and from 40 degrees to 50 degrees in the short span, facing north. In order to obtain an angle of 32 degrees in the roof, it should rise 7½ inches per foot horizontal. A 6-inch rise in the roof per foot horizontal gives an angle of 26 degrees.

DISTANCE BETWEEN HOUSES

Just enough space should be left between detached houses to keep one from shading the next and to prevent waste of land. Theoretically, the exact distance between houses can be measured by drawing the existing house to scale on paper and measuring an angle of 25 degrees (height of sun above horizon at winter solstice) to a horizontal at its ridge. Then carry this angle line down to the ground and measure according to the scale used, the distance between the house and where this line strikes the ground, or would strike the sill plate of the next house. Practically, this distance can be figured as equal to the height from ground to ridge of the house next to it.

The space between houses need not be wasted but can be used by placing hotbeds or coldframes there, which can thus be easily heated from the greenhouses. Many growers also use this protected space for planting peonies or a similar hardy crop so that they will be in bloom considerably earlier than out in the field.

WIDTH AND LENGTH OF HOUSES

The question as to what width of house is best to build can only be answered by saying it depends on the crop to be grown, space available, and the amount of money to be expended.

Some growers still consider the narrow house unquestionably best. Many of the growers of pot plants find it a decided advantage to have small houses where they can

meet the individual requirements of certain groups of plants, necessarily limited in the quantity grown. Pot plants cannot be successfully and economically shipped great distances and so there is a limit to the number that can be profitably grown for a given locality.

It has been most conclusively proven that best results with cut flowers and vegetables are obtained in the wide house. The wide houses are best because they are more economical to heat, they cast less shade and are easier to ventilate and work. In such houses, in spite of the high ridge and the large volume of air there is to heat, when once heated it stays heated with less coal than the small house. The large volume of heat acts as a sort of storage or insulating surplus against sudden changes, so that varying outside temperatures have only a gradual effect. Sudden changes in temperature are thus largely prevented. There is a noticeable thriving buoyancy to the air in big houses, more like the fresh air outdoors. The large volume of air when fresh stays so for a longer period.

When opening the ridge ventilators the air has some distance to go, so that it is well tempered before reaching the plants. The shade from the superstructure is so diffused that its effect is greatly lessened. Also, in large houses the work is more efficient. In proportion to the ground space covered, large houses cost less.

Houses of small widths would be anywhere from a 10-foot propagating house up to 30 feet wide. Houses of 40 feet to 60 feet would be considered wide houses. Beyond this width it is not practical to build, because the roof pitch must be small in order to avoid an extra amount of superstructure to support a high ridge. With a small angle roof pitch the house would not clear itself readily of snow and ice.

Houses from 30 to 40 feet wide may be called "happy

medium" widths and general purpose houses. The majority of houses built today probably fall in this group.

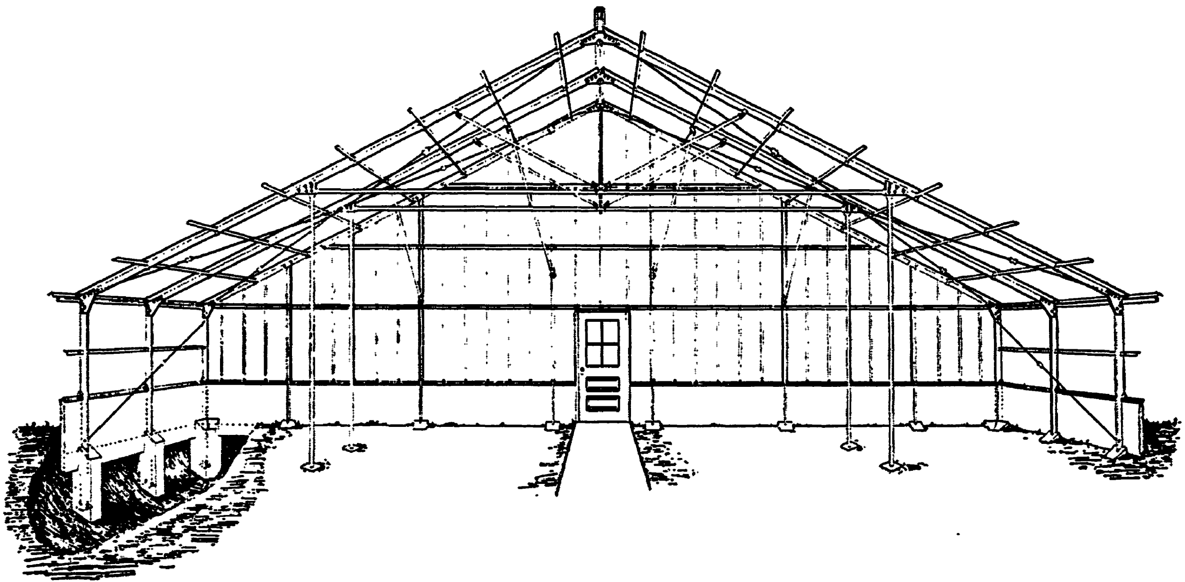
In the west, houses from 30 to 40 feet are built ridge and furrow style and have been found good practical, economical structures.

The question of how wide a house to build resolves itself into a problem of calculating the best arrangement of the benches and beds in them in order to get the maximum growing space. It must be remembered that on the average this actual growing space is only about 60 to 70 per cent of the total floor space of a greenhouse, the remaining 30 to 40 per cent being used for walks.

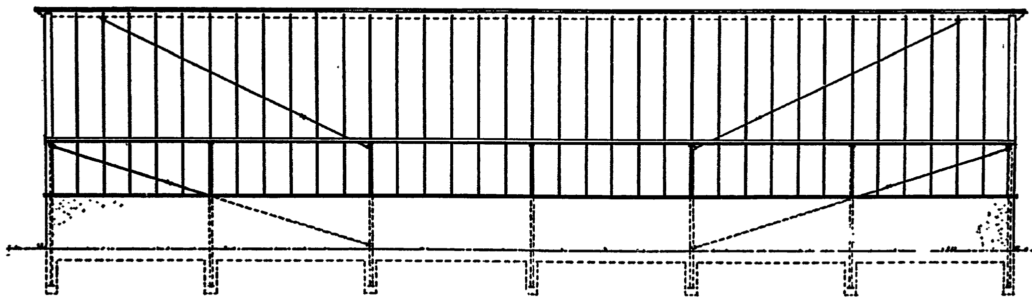
Most greenhouse construction concerns have what they call "standard size houses" in which they attempt to give the grower the best interior arrangement, in an assortment of sizes. These houses are more ecoomical to buy than an odd-sized one, because materials for them are prepared in advance in large quantity and so can be manufactured more cheaply.

The length of the house is not so important a consideration as its width and is governed almost entirely by the amount of money to be expended. A beginner would probably start with one 50 feet long, then increase it to 100 feet or 200 feet. In this case the gable end on the shorter house can, of course, be used on the longer one. A house 500 feet long is generally considered about the limit in length efficiency.

Another consideration with regard to the length of the house is that the further end of it should not be too far from the heating system. This would cause sluggish return of water to the boiler unless return traps or pumps were installed.



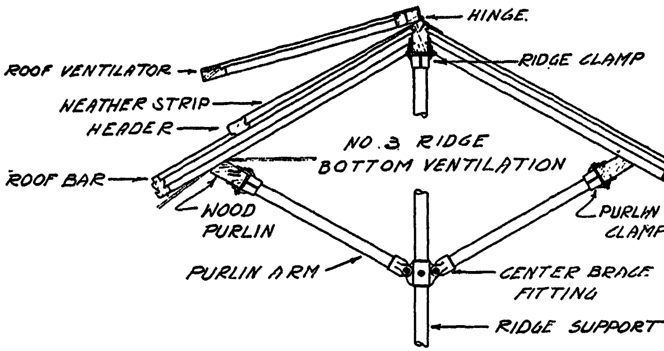
Gable End Bracing, Houses Over 40 Feet Wide
Iron Frame Construction



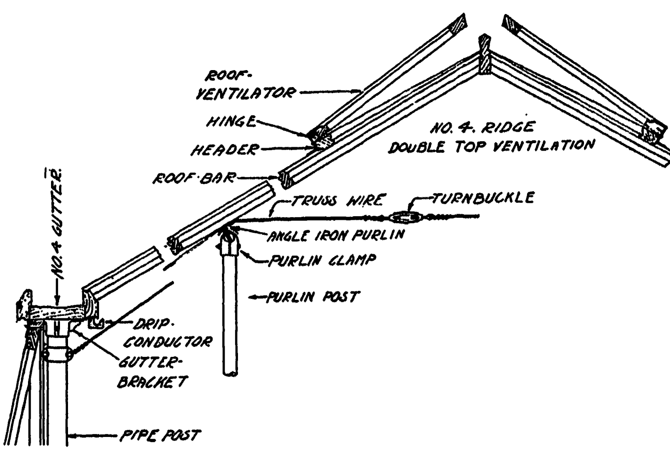
Wind or Sway Rods Used in Houses Over 25 Feet Wide at Gable Ends, Sides and Roofs

ROOF BRACING

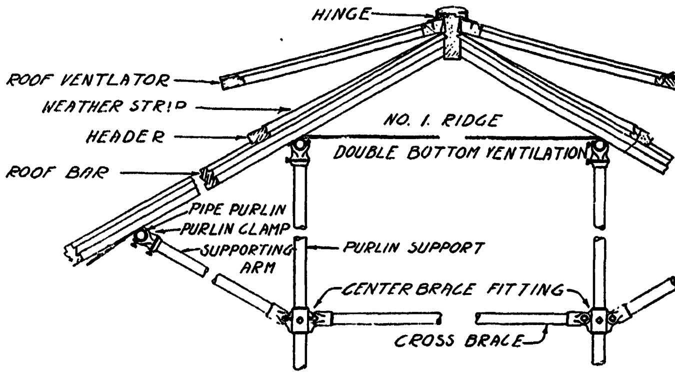
SEMI-IRON CONSTRUCTION. PIPE SIDE POSTS



Single Y brace for houses not over 20 feet

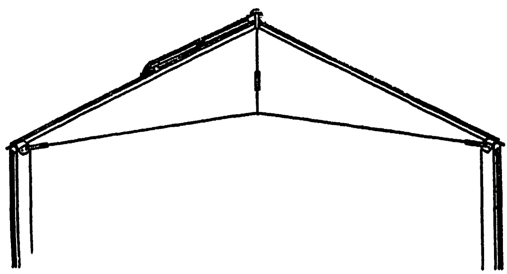


Two posts and truss wire for houses not over 25 feet

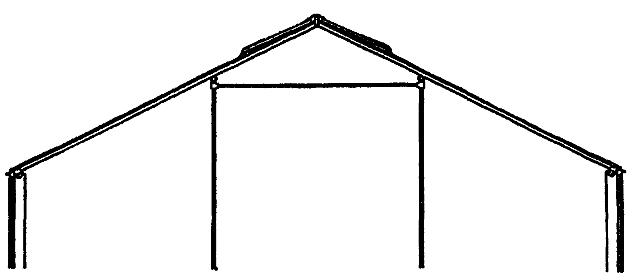


Double Y bracing for houses not over 35 feet

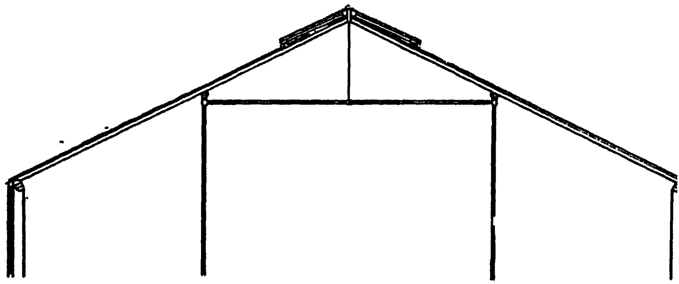
FLAT IRON SIDE POSTS



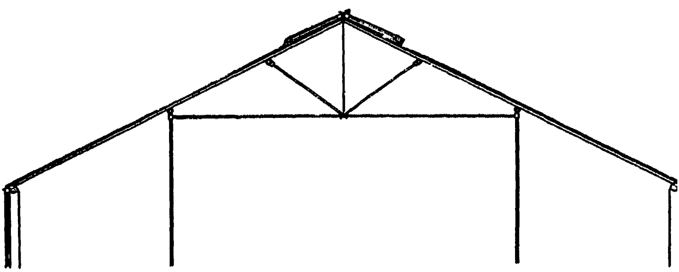
11-foot house
Truss rod from eaves and to center of ridge to prevent spreading



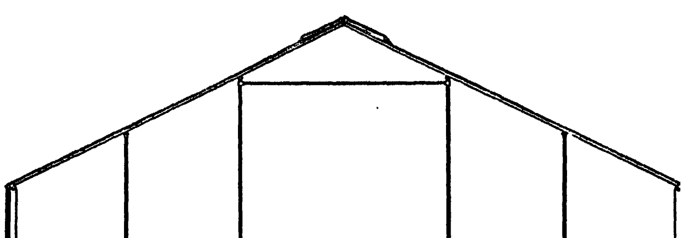
18-foot house
Two posts and cross brace



21-foot house
Two heavy pipe posts, cross brace and truss wire from ridge

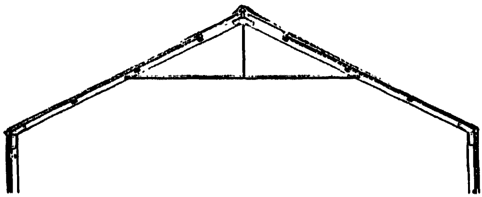


28-foot house
Two pipe posts cross brace, V brace and truss wire

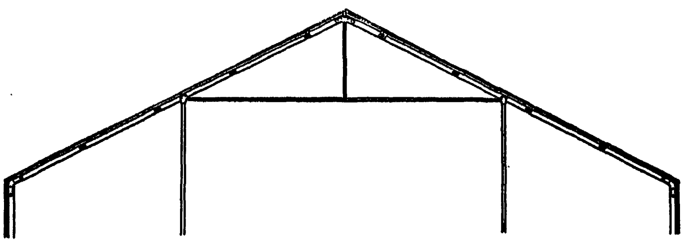


32-foot house
Four pipe posts, center two with cross brace

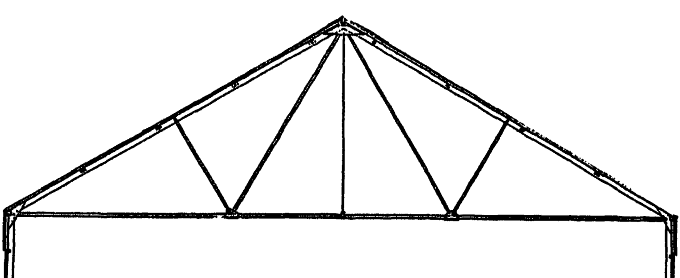
IRON FRAME CONSTRUCTION



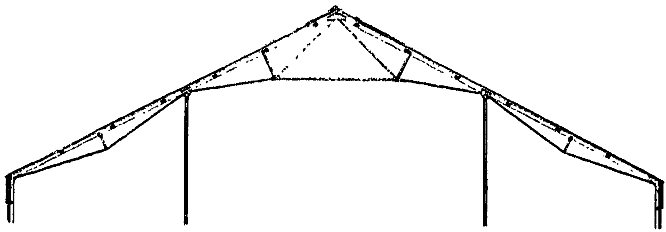
No interior posts in houses up to 30 feet wide



Houses 35 to 40 feet wide require but two posts

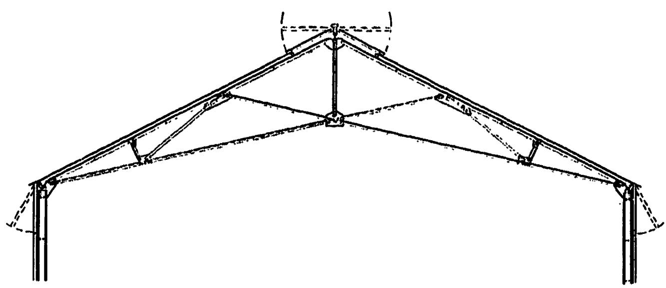


Compression truss for 40-foot vegetable house to eliminate posts

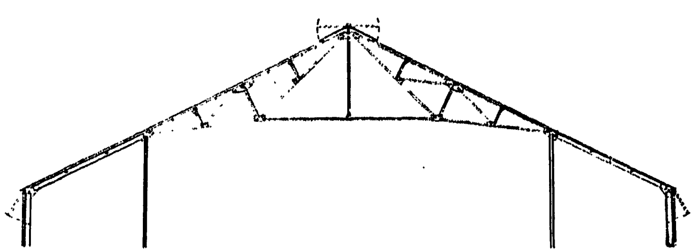


Compression truss, 60-foot house, only two posts

SPECIAL TRUSSES FOR IRON FRAMERS



Scissors truss used in houses up to 40 feet wide to eliminate posts



Fink truss for houses over 40 feet wide

CHAPTER IV

Arrangement of Greenhouse Range—Types of Greenhouse Construction—All Wood—Semi-iron Frame—Iron Frame Home Construction vs. Contract

MOST greenhouse ranges have had small beginnings, the owners little realizing when they began how large their place would be ten years hence. Therefore, one must have foresight and imagine how things will be in the future. The location of the boiler plant and the first house will govern everything done afterward. In many of the older ranges the future was not considered, with the result, that the range as the new houses were added, became a jumble.

The present-day arrangements favor what is called a "Balanced Plan." The boiler house, workhouse or potting shed and packing house are combined into one and centrally located and separated passage-connecting houses are built on either side. Such a layout means an economically balanched distribution of heat and equalizes the distance in working the houses. Furthermore, if the houses are built of the same size, they can be worked as units, knowing exactly what it will cost to crop each and approximately what crop to expect. The adding of a house will mean a certain definite addition of heat and help. This latter suggestion of houses all of a uniform size probably is more applicable to the crop specialist than the general grower.

The balanced plan may be modified to some extent as in the case of a location with a southern slope. In this case the boiler and workrooms would be best placed at the lowest level on the south of the houses, but must be sufficiently distant so as not to cast shade on the houses above. Such

a hillside location should not be steeper than 25 degrees, otherwise it will be difficult to work.

Again, a plan might be adopted, placing the boiler and workroom toward the north of the greenhouses. In both these cases the best direction for the houses would be east and west. This unbalanced plan, however, should follow the idea of parallel houses and connecting houses connected centrally with the boiler room.

Some rose growers prefer to place the houses from 10 to 15 degrees north of east in order to get the advantage of the morning sun a trifle earlier. The morning sun is more beneficial than the afternoon sun and in this northeast by southwest arrangement the vegetation is started earlier in the morning. While in general an east and west arrangement of greenhouses is preferred there is no strong argument against the north and south arrangement, provided the houses are of the even span construction.

TYPES OF GREENHOUSE CONSTRUCTION

There are three main types of greenhouses, based on the materials used in their construction. These are, all wood frame construction; semi-iron frame construction and iron frame construction.

Just what type of house is best to build depends upon a number of factors. After discussing the various merits and demerits of each type we can perhaps arrive at some conclusions.

ALL WOOD CONSTRUCTION

In the all wood construction, all members, including side posts, are of wood. Some advantages of this type of construction are that the members may be cut and fitted by any builder and that in small sizes this construction is cheaper. With proper care as to painting and repairing, this house will last from 15 to 20 years or more, at which time posts will probably need replacing.

The disadvantages of a wooden house are that the members must be larger and closer together than if metal were used and therefore more shade is cast. Likewise there is likely to be more decay of members, especially the posts.

Wooden houses with wooden side posts should not be over 20 to 25 feet wide, because beyond this width so many interior posts and purlins would be necessary to support the roof as to interfere with the easy management of the house. The wooden side posts should be 4x4 inches, set in concrete and placed every 4½ feet apart from center to center. Wooden purlins should be 1¾x3¾ inches, with the sash bars 1⅝x3 inches. The purlins are supported on the interior of the house by 1¼ inch pipe posts, with 1 inch pipe arm braces. The purlins should be placed 5 feet apart, each supporting post or arm brace 5 feet apart also.

Modifications of the all wood house are generally built

Interior of Wood Frame House with Pipe Supporting Posts and Purlins
Note north wall boarded. Ground beds

today, in which pipe side posts are used instead of the wooden ones. Pipe purlins also replace the wooden ones. These add strength and decrease shade, because 2 inch pipe posts placed 8 feet 4 inches apart are used instead of 4 inch wooden ones placed 4½ feet apart. Also 1¼ inch pipe purlins replace the 1¾x3¾ inch wooden ones; such houses may be safely built up to 35 feet wide. A double "Y" post support is used for the roof. This construction is quite similar to the semi-iron type of construction, but differs in that wooden sill plates, eave plates or gutters are used.

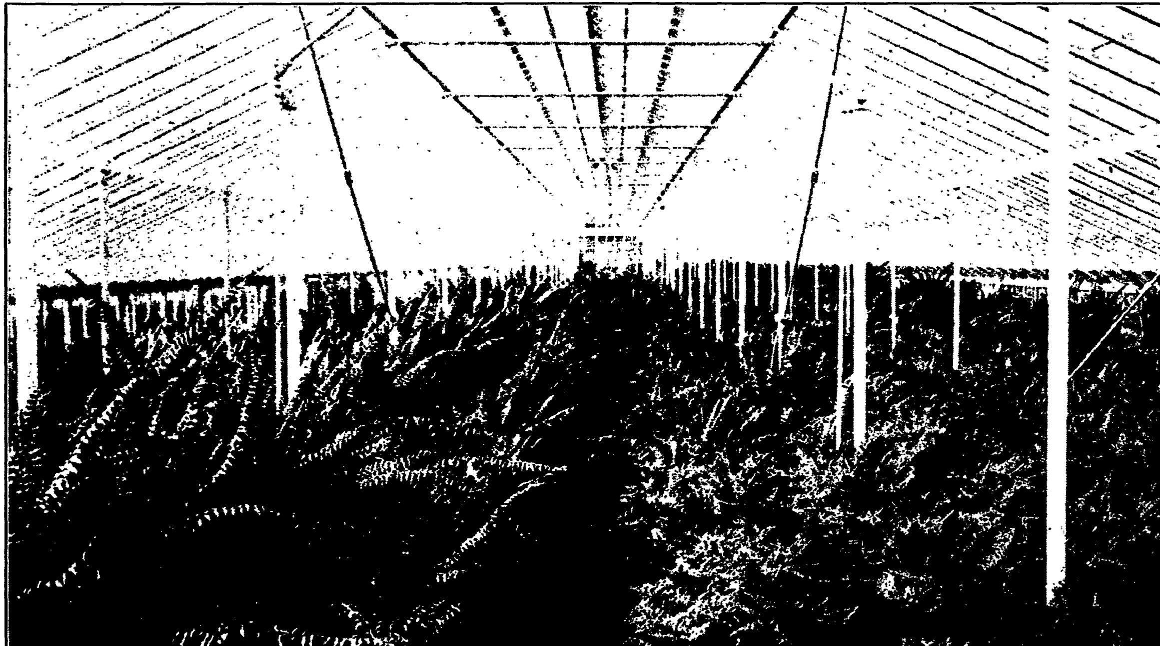
The small wooden house is a good proposition for the beginner because he can readily build it himself. It may require greater annual outlay of money to keep it in repair but is cheaper to begin with.

The wooden house of today is quite a different affair from the old-fashioned wooden houses. Modern sized glass is used and so it is almost as light as the half-iron or iron frame houses. At least for most crops it is light enough, although out of the question for roses.

If the modern type of angle iron eave plate is used in place of the wooden one, the eave too will clear itself readily of ice and snow, which was one objection to the old wooden houses. Again it might be said that the modern wooden eave plate is not the cumbersome one of years ago and it clears itself quite readily in winter also. The iron eave plate will rust badly if not kept painted.

SEMI-IRON FRAME CONSTRUCTION

Modifications of the all-wood house lead to the type of construction called semi-iron frame. With an effort to so introduce stronger supporting posts of iron and make the wooden house lighter, the half-iron construction has been evolved. This is really a stretching of the wooden house so it can be built in larger widths. It is used in houses of small sizes up to about 35 feet wide. If built in the larger sizes, a



Modern Semi-iron House About 35 Feet Wide

great amount of roof supporting posts and braces are necessary, which increases the cost and decreases the light.

The semi-iron construction is more expensive than the wooden construction but is stronger and more durable.

The side posts are made of flat wrought iron or steel, ½ inch thick by 3½ to 4½ inches wide, according to the width of the house. Wrought iron pipe posts of 2 inches diameter are sometimes used instead. An objection to pipe posts, however, is that they rust from the inside toward the outside. The solid iron post overcomes this objection and is therefore more in favor. When pipe side posts are used it is known as the pipe frame construction.

These posts are set 8 feet 4 inches apart. A cast-iron sill plate and galvanized angle iron eave plate are used. The remaining members are of wood. Two-inch interior pipe posts are used for supporting the 1¼ inch pipe purplins, these being 5 feet apart.

The sash bars are 1⅜x2½ inches in this construction as compared to 1⅝x3 inches for the all-wooden house.

IRON FRAME CONSTRUCTION

The iron frame type of construction is perhaps the most expensive type but the most durable of all. Its erection cost is less than that for semi-iron. It is best used in all houses over 35 feet wide.

Iron frame construction differs from the semi-iron type in that a flat iron rafter is used, fastened to the top of the side posts with gusset plates and joined at the ridge with special plates.

Angle iron purlins are fastened to these rafters, thus making a complete framework of metal over the entire house. The sash bars then function merely as supports for the glass, and do not hold up the roof as much as in wooden or semi-iron construction. The bars can be of smaller sizes for this reason, 1⅛x1¾ inches.

The side posts and rafters are generally placed 8 feet 4 inches apart, but in recent modifications of the iron frame house, this distance has been increased to 12 feet 6 inches for the rafters, using a side post in between. In some large truss construction the rafters are increased to 16 feet 8 inches between, but channel bars are generally used in place of the flat iron post and rafter. No interior posts are required in this type of roof support, making the interior of the house easy to work with no posts in the way. Men who force vegetables on a large scale like such a house because they can plow and harrow the land as readily as outdoors.

The iron frame houses are easy to erect since the rafters and bracers can be bolted together on the ground and then hoisted in position on the posts and the bolts slipped into place. One greenhouse manufacturing concern hot-rivets the truss work for the arch truss construction at the factory and it is shipped all assembled. After the eave plate and ridge are in position the sash bars can easily be put in place. Thus in the iron frame construction the builder has a framework to rely on and once this is up the remaining construction readily fits in place.

The iron frame construction is probably more used by the grower who specializes on a large scale in one crop than by the grower of a variety of crops.

SUMMARY

After having briefly discoursed on the types of greenhouse construction it might be well to sum up the facts.

In the first place, the all-wooden house with wooden purlins, wooden posts, eave plate and sill is not built today to any great extent. The modified wooden house, or in reality the semi-iron house is the most popular type for those who grow a variety of crops and therefore want medium sized houses from 20 to 35 feet wide. The iron frame house is the house for the wholesale specialist of roses, carna-

tions, cucumbers, or tomatoes, as he must grow one of these crops on a large scale to make money and so needs large, wide houses.

HOME CONSTRUCTION *vs.* CONTRACT

The material which is used in the construction of modern greenhouses is practically all milled or shaped at the factories of greenhouse manufacturing concerns. It does not pay to try to manufacture this material locally. There are a number of reliable construction concerns from whom these materials can be obtained. One must decide what size and type of house to erect and order the materials accordingly. These companies give advice freely to prospective greenhouse builders as to the house most suitable and furnish blue prints with specifications as to their erection.

Small houses may be satisfactorily erected by the amateur, if he is mechanically inclined. If the blue prints and specifications furnished by the concern from whom the materials are bought are closely followed, no difficulty should be experienced in the erection of houses up to about 25 feet wide. In the erection of houses wider than this, experience has shown that it is more desirable to have the company from whom the materials are furnished do the erecting. However, even in this case, the grading work, the building of the concrete side walls, the installation of water pipes or plumbing can be more economically taken care of locally.

The cost of erection of a house by a greenhouse building concern will vary according to each particular job, but in general it will be about half as much as the cost of the materials. It is well to have the builder contract to have the house finished by a certain date so that no delays in planting will be encountered, which means loss of returns from crops.

It is desirable to receive bids from several concerns as to the cost of the materials and erection for a given greenhouse, so that one may take advantage of the best price. However, the lowest bid is not the only consideration, for the kind of materials supplied must be studied. The following points should be carefully compared when making a study of prices from several concerns:

Square feet of ground area covered
Total square feet of roof and gables
Kind and amount of side walls
Type of sill plate and eave plate
Number, kind and size of purlins
Kind and size of side posts and rafters
Number of runs of ventilating machinery
Amount and kind of glass
Size, kind and grade of wood
Paint, quality and amount
Putty and brads, as to kind and amount
Total feet of heating pipe; also kind of pipe
Kind of boiler
Square feet of grate area
Kind and number of valves
Covering of boiler and mains
Freight charges
Cartage

It may be generally stated that one gets what he pays for in the way of greenhouse materials. The cheapest house is not always the best house to build. The actual kinds and amounts of materials going into a house must be considered.

CHAPTER V

Instructions for Erecting Semi-iron Frame Houses

IN VIEW of the fact that the beginner will probably build his first house of the semi-iron frame construction, instructions are here given to guide him. Only one who is a good, careful mechanic and has an idea as to the peculiarities of a greenhouse should attempt to erect one. The ordinary house carpenter, glazier and painter must first be made to realize that a greenhouse is a sun factory.

Greenhouse construction is very exacting and errors in measurement, or imperfect alignment, etc., must not occur or difficulties will arise. If one feels he has mechanical ability or can have some one work with him who has constructed greenhouses, a good saving can be made. Otherwise it would be far better to have experts from the greenhouse concerns erect the house, because they are familiar with the various pitfalls of such construction and can build it in a much shorter time.

Nevertheless the following instructions will be of interest to all:

The ground should first be made level and if natural drainage is poor, tile drains should be laid. This is very important because large quantities of water are used and unless it can drain away readily, damp conditions will prevail which are detrimental to the health of the plants, as well as to the life of the greenhouse members, more especially the posts.

On low, heavy land, the ground should be raised by filling in with gravel, to insure good surface drainage. A

6-inch layer of gravel will be found very desirable over the soil of any greenhouse location, because in addition to drainage, the interior floor surface can be nicely leveled which will make things easy in the building of the benches.

The following detailed instructions with diagrams are here given through the kindness of the Lord & Burnham Company. They are very explicit and will enable one to have a better understanding of the practical side of greenhouse construction. While these instructions refer to houses of semi-iron construction, the preliminary instructions hold good for all types.

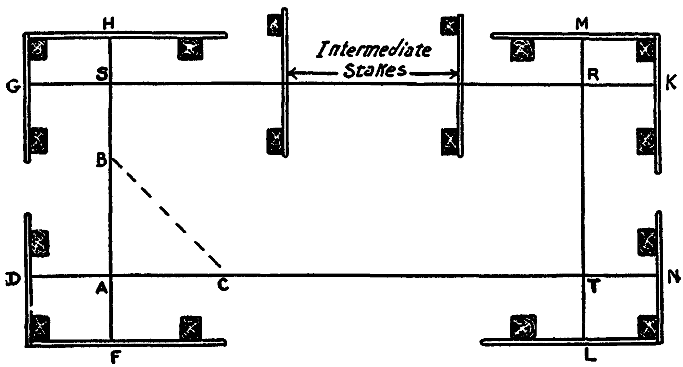


Figure 1. The first step in laying out, is driving of stakes for nailing on the batter strips. This gives you a safe and sure method of getting both the post lines and grade right

"In laying out a greenhouse, the first process is to drive two stakes whose distance apart is approximately the width of the greenhouse. Around these two stakes drive other stakes to which are nailed batter boards. (See *Figure 1*).

"In the same way put up the batter boards at the other end of the house, keeping these as nearly at right angles to the first stakes as possible. These batter boards should be at least 2 feet away from the exact width and length of the

house, so that they will not be in the way of erection. It is a good plan to keep the batter boards 1 foot or some convenient distance above the finished inside grade line.

"If the house is to be given a patch, the high end of the house should be the farthest side from the workroom. The batter boards should be raised at the high end according to the pitch the house is given. An average pitch of 6 inches per 100 feet is given long houses.

LAYING THE FIRST LINES

"There are two methods for laying out the lines, one by drawing the lines through the center of the post hole, and one by drawing the line to one side. The last method is preferred and is used in these instructions, for the posts can be set straighter if they are set away from a straight line than by setting them exactly on the lines.

"By a straight line is meant a cord line that is taut, and no sags in it. If sags occur, enough intermediate stakes should be put in (see *Figure 1*) to carry the line without sagging.

"Measurements should be made with a steel tape.

HOW TO SQUARE UP THE LINES

"To lay out the cord lines, first fasten the line DN (*Figure 1*) to the top of the batter boards.

"Then fasten the line FH permanently at F and temporarily at H.

"Next see that these two lines are square or at right angles to each other. To do this, lay off a distance AC on DN equal to 3 feet.

"Then lay off a distance AB on FH equal to 4 feet.

"Then if the two lines DN and FH are at right angles to each other, the distance BC will be 5 feet. If BC does not equal 5 feet, adjust the line FH at H (the temporary fastened end) by moving the line one way or the other

until the distance BC equals 5 feet and AB equals 4 feet, AC equals 3 feet.

"It is well to take longer distances for AB and AC if possible, as the larger the triangle formed, the less chance for inaccuracy. Therefore, the table is given below.

"In table: C=AC B=AB A=BC.

"For example, if your house is 30x75 feet, then from table take AC 15 feet, AB equal 20 feet, then BC would be 25 feet.

"After squaring these two lines, lay the cord line GK exactly the width (from outside to outside of iron) of house from the line DN and parallel to it.

"Then lay the line ML parallel to FH and a distance away equal to the exact length of the house (iron to iron, outside measurement).

"Check the corner at R to see if these last lines are square.

"If the distance between the points A and R is exactly the same as the distance between the points S and T, the house is exactly square.

TABLE FOR SQUARING UP LINES

C	B	A
3	4	5
6	8	10
9	12	15
12	16	20
15	20	25
18	24	30
21	28	35
24	32	40
27	36	45
C=AC	B=AB	A=BC

By following the measurements in this table and the directions under heading of "How to Square Up the Lines," you can be sure your lines are laid out square. Don't slight this part. It is of greatest importance that your *start is right*

FASTENING LINES TO BATTER BOARD

"When the lines are laid out square with each other and the right distances apart, they should be permanently fastened to the batter boards as shown in *Figures 3 and 4*.

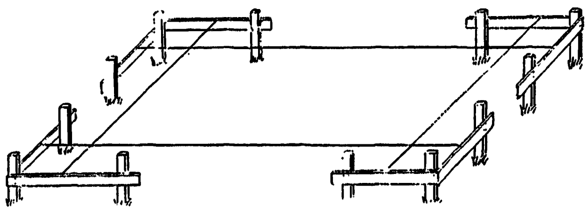


Figure 2. Another view of stakes and batter strips for carrying the final layout lines

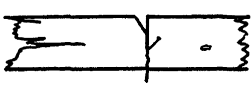


Figure 3. Showing batter strip with notch for holding line in place and nail to fasten it to

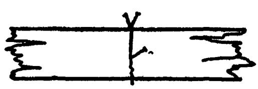


Figure 4. Batter strip with two nails driven V-shaped in place of notching the wood. One way is as good as the other

Figure 3 shows a notch and line fastened by nail underneath. *Figure 4* shows a nail driven on each side of line and as close as possible and line fastened underneath by a nail.

STAKING POST HOLES

"The next step is to stake the post holes.

"First drive a stake under the crossing of the lines HF and DN at A and at the crossing drive a small wire nail into stake.

"Slip ring of steel tape over the nail.

"Then as the centers are 8 feet 4½ inches, a stake should be driven 8 feet 4½ inches from A. Another at 16 feet 9 inches, another at 25 feet 1½ inches, at 33 feet 6 inches, at

41 feet 10½ inches and at 50 feet 3 inches. If the house is longer, repeat the operation.

"All measurements being taken from original point, except when operation is repeated, when the stake at the 50 feet 3 inches is taken as the original point. In this manner all the post holes are to be staked out.

CAUTION ABOUT STAKING HOLES

"A great danger in laying out the stakes for the post holes lies in the fact that the amateur taking a rule or rod and going along with this rod, spaces each one separately. If he should vary ¼ inch in one space or in each space, of course his holes will not come out right at the end. So follow the instructions in every detail and you can't go wrong.

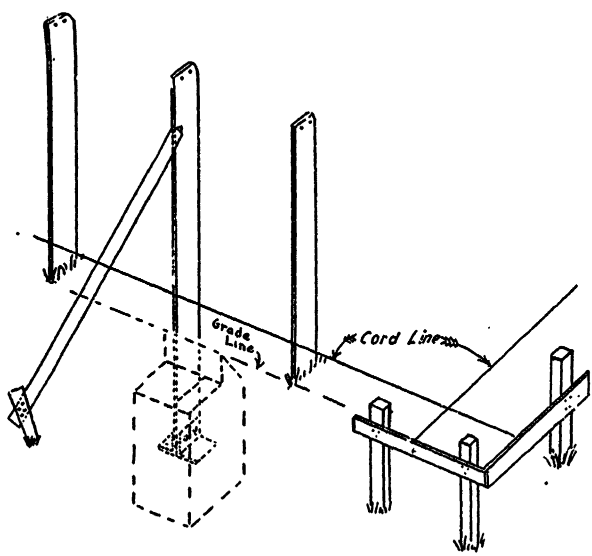


Figure 5. Here you have the outside edge of the posts faced up against the *inside* of the line

DEPTH OF HOLE AND HEIGHT OF CONCRETE

"In digging the post holes, the distance from the cord line to the bottom of the hole should be determined and a rod cut the proper distance from the line to the bottom of the hole.

"The post hole should be 6 inches lower than the permanent foot of the rafter. This is to allow for 6 inches of concrete for the bottom of the hole.

"If another rod is taken from the cord line 6 inches shorter than the first rod was made, this will locate the proper height of the concrete in the hole wherein the post foot sets.

"By using this rod to each post, it makes the concrete absolutely correct and the proper pitch or level, as it may be the same, though it was located above ground by line.

SETTING POSTS

"The ironwork is now started.

"Take the posts as numbered on plan, and leave at post hole where they belong. On each post mark (file mark preferred) should be made on the outside edge of post (at a distance down from the top equal to the distance X, see *Figure 7*) from top of post to grade line minus the distance Y the cords line has been set above grade.

"Now set the post in the hole making the file mark on the post come to the same level as cord line and just barely touch it.

"Make the post plumb to cross grade but at right angles to grade in the length of the house. Brace post as shown by *Figure 5*.

"The corner post should be set first and a rod 8 feet 4 inches long should be used for spacing off sideways.

"In the same manner set all the side posts so that each one just touches the cord line at the file mark. This would insure an absolutely straight line.

"Care should be taken in spacing off sideways, to measure with a steel tape to check on rod.

"It is important that the posts should be the same distance between the top and bottom and that they are plumb with those across the house.

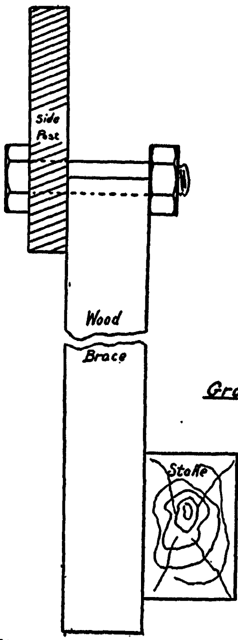


Figure 6. Method of bracing side post

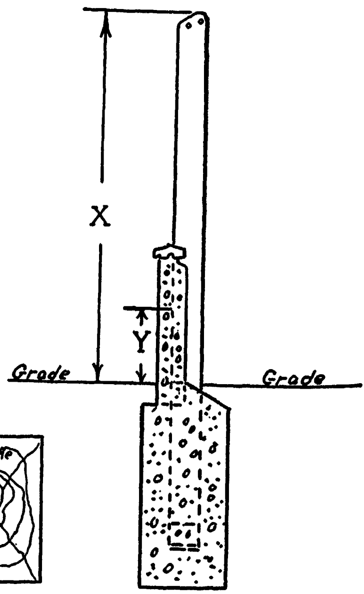


Figure 7. Cross section showing concrete sides and footing.

"Gable posts and inside supporting columns should always be made plumb, both ways to grade.

CONCRETE PIERS

"The concrete piers in which the side posts are set should contain at least 2⅛ cubic feet of concrete composed of one part of cement, three parts of sand and five parts of stone. This should be placed in a hole not less than 1 foot in diameter and should be brought to grade.

"From grade to 3 inches above grade, the top of the pier should be brought on a bevel up to the post in order to protect the post from the water on the inside of the house. See *Figure 5*. Top of level is shown as top of grade.

EAVE PLATE

"After the side wall and interior posts are set, fasten on the eave plate to the top of the posts.

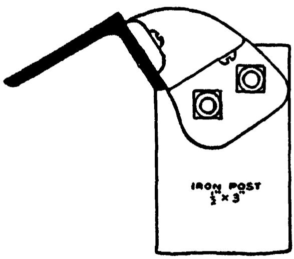


Figure 8. Post with eave plate secured to it by the eave bracket

"It should be seen that the eave plate is perfectly straight without sags up and down, and should there be any hollow place this is the time to make it good.

"The eave plate and narrow cast-iron sill, when used in place of cypress sill, are gotten out a scant 1-16 inch short. This is to allow for expansion.

"Therefore, these should be put up with a scant 1-16 inch between joints.

"Before putting up the eave plate it is best to attach the sash bar clasps.

"Now sight along the eave plate. If it is placed in proper alignment, we are ready to fill the concrete in around the posts, having checked the spacing with a steel tape.

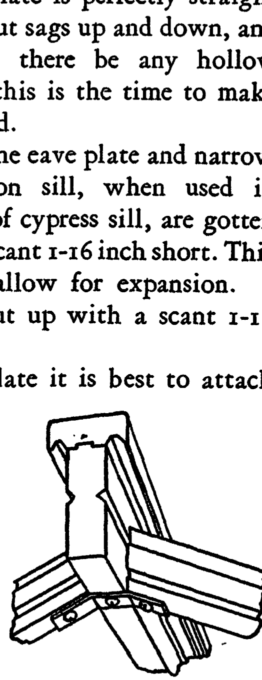


Figure 9. Before putting up, screw the ridge brackets to the ridge. The holes are already spaced and started. The bars are screwed to the bracket and toe-nailed to the ridge

RIDGE BARS

"After the posts and eave plate are all set, it is an easy matter to put up the ridge bars and the rest of the woodwork.

VENTILATING

"The ventilating shafting can now be put up, and, in doing this, the hangers should first be fastened to the bars and the shafting slid through, putting on the necessary arms for each bay at the same time. The shafting comes in bundles, one bundle being one complete run with coupling to attach to gear.

Figure 10. Ventilating shaft hanger screwed to the roof bar

CONSULT PLANS

"In following out these instructions, the plans which are furnished by the manufacturer should be consulted frequently, and the person doing the erection work must make himself very familiar with them so that the work will go along smoothly and accurately."

The above instructions are general, and are as full as can be made in a book of this kind. When materials for a greenhouse are purchased, full detailed instructions accompany the order.

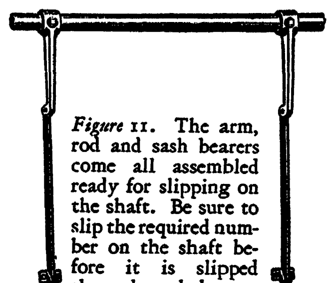


Figure 11. The arm, rod and sash bearers come all assembled ready for slipping on the shaft. Be sure to slip the required number on the shaft before it is slipped through each bearer. With the sash down tight and the arms pulled snug, then fasten down the set screws

CHAPTER VI

Ventilating Greenhouses—Painting and Glazing—Shading Glass—Brackets—Benches, Beds and Walks

VENTILATION is necessary in greenhouses to provide a supply of fresh air and to control temperature and humidity. It must be given careful consideration because greenhouse plants are particularly sensitive to cold drafts. Greenhouses, with their transparent roofs are subject to sudden changes in temperature, especially on days of alternate cloudiness and sunshine. Ventilation can then equalize the temperature.

The air in a greenhouse is warmer than that on the outside. This warm air tends to rise and means for its escape must be provided in order to start a circulation of the air to make ventilation effective. The cool air on the outside finds its way through the laps of glass into the house. This cool air goes toward the floor of the house and as it is heated it rises again. For this reason the most effective location for ventilators is at or near the ridge. The warm air can escape at the highest part of the house and the cool air filters in through the panes of glass without causing drafts.

The ventilators, which are in the form of sash, are generally hinged at the ridge and rest on the ventilating header placed across the sash bars. Some growers prefer them hinged at the header and resting on the ridge. They can be opened to any degree desired. Narrow ventilators, continuous along the whole length of the house, are best. These ventilators should be glazed with the same width glass as that used in the house so that their bars fit directly over the sash bars of the roof. It is well to have the roof

ventilators on both sides of the ridge in houses 30 feet wide or more, to provide a large enough opening. In this case, too, the ventilator on the side away from the prevailing wind can be opened. In smaller houses ventilators on one side of the ridge are all that are necessary, that is on the south side of east and west houses and the east side on north and south houses. Only the roof ventilators are used during the winter. The width of the ventilating sash should be about 24 inches in houses up to 40 feet wide and 30 inches in houses above 40 feet wide. They are on the average about 8 feet long and are fastened end to end with galvanized metal plates.

Ventilators are sometimes placed on the sides as well as on the roof. They can only be used in the spring, summer and fall, however, for in the winter if opened they would expose the plants to a direct cold draft. Probably not more than half the commercial greenhouses are equipped with side ventilators for the reason that they are not of much use, and so the extra cost of their installation is saved. They are however convenient in the spring, summer and fall on warm days to help moderate the temperature in the house. They can best be used in houses which have no side benches. When used they are hinged from the eave plate or from a fascia strip placed under the eave plate, and open outward and up. Side ventilators on the south side at least would be a good proposition. In the moving of soil from and into the houses, these side ventilators would be a great aid, as it would eliminate much wheeling down through the length of the house, as the soil could be thrown through them. However, to facilitate this removal of soil, some houses are equipped with sash or panels in the sides which can be taken out when emptying and filling the benches.

In wide houses, 60 feet and above, ventilators are placed in the gable ends also.

In conservatories, orchid houses and show houses with

curved eaves, instead of the side ventilators being placed above the side wall, a system of panels which can be opened are placed in the concrete side wall. This allows the cool air to enter under the side bench and so not come in direct contact with the plants. The cool air is quickly heated by the heating pipes placed at the side walls. This system has never met with favor in commercial houses, however.

In a house with a 6 foot or 7 foot eave a 20 inch side ventilator may be used, hung from the eave plate and stationary glass used below this to the sill. This prevents cold air from blowing directly on the plants.

There are various types of sash-operating machinery but their operating principle is the same. In the first place, a horizontal shaft is firmly fastened near the line of ventilating sash. Then a system of gearing is used by which power, applied at a point convenient to the operator, is transmitted by a perpendicular rod or chain to this shaft and rotates it. The arms or levers, attached to this shaft and the sash, raise or lower the latter.

The horizontal shafting generally used is 1 inch or 1¼ inch wrought iron or steel pipe. The pipe lengths are generally clamped together with malleable iron couplings. The wrought pipe comes in two weights, standard and extra heavy, 1 inch standard strength being used in shafts up to 50 feet long; 40 feet of 1 inch extra heavy and 35 feet standard strength in shafts up to 75 feet long, and 1¼ inch extra heavy in shafts up to 125 feet long.

This shafting is held in place by means of hangers which are fastened to the sash bars, supporting posts or rafters. When fastened to the sash bars, a hanger is placed usually on every second bar. Overhead shafting is hung from the rafters in iron frame houses and that for the side ventilators is fastened through the side posts.

The most common type of arm is the elbow arm; it is generally used in small houses for both roof and side

ventilation. A long leverage is required in order to open the ventilators wide; this is one disadvantage in using this type of lever; also it puts considerable strain on the shaft. On long runs the double-acting arm is used to some extent as it gives a wider opening with a shorter leverage.

The extending or folding arm is sometimes used for side ventilation, where the elbow arm would be in the way of a walk along the side of the house. It lacks, however, the strength for long runs.

Another type of lever used to open the sash is the rack and pinion. Its advantage lies in the fact that there is less of a twisting strain on the shaft and it is more powerful The hand-wheel must be turned several revolutions more to open the ventilators in this system than with the elbow arm. It is used to quite an extent to operate long runs of ventilators.

These arms or levers are clamped securely to the shafting and as near as possible to the hangers so as not to spring the shafting when heavily loaded. They are generally spaced 3 feet apart along the run of ventilator.

In order to revolve the horizontal shaft which in turn moves the elbows, thus opening and closing the ventilators, there are several types of gears used. These gears are usually moved by perpendicular driving rods or shafts which are generally securely fastened to the interior center posts in semi-iron houses or fastened to the rafters in iron frame houses. The column gear is the most common for small and medium-sized houses. In this type a post or column supports the gearing and the hand-wheel to which power is applied.

In the open column gear, the perpendicular drive rod is not enclosed in a column and there is no housing about the gears. In the closed column or closed gear type, the driving shaft and gears are entirely encased and the latter run in oil as in the transmission case of an automobile. In this case

Compact Side Ventilating Machinery

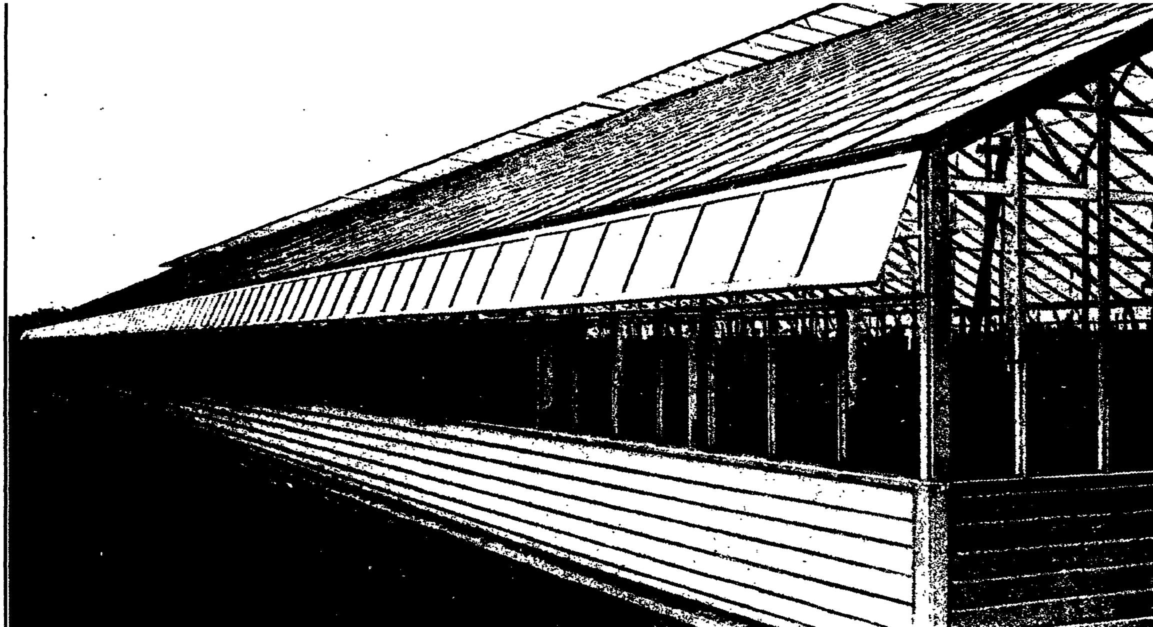
the gears do not get rusty and they operate easily and noiselessly. The base should be firmly set in concrete.

Where chains are used in place of a perpendicular rod to transmit power, they have several advantages. The absence of columns means less shade and is preferred by some vegetable growers because the chains can be slipped off the hand-wheel, the base standard lifted out and the center space left entirely free to drive in for soil filling. A special movable base standard must then be used. Ordinarily this base standard is set in concrete.

The counterbalance gear type of ventilation works on the principle of having weights in the hand-wheel standard to counterbalance the weight of the sash. The weights are so arranged that the sash will run smoothly down of its own weight and stop within a few inches of closing. A twist of the hand-wheel then brings the entire run of ventilators down tight at all points. This counterbalanced gear will operate sash in lengths from 100 feet up to 200 feet and the rack and pinion leverage is used in place of the arm and rod beyond 100 feet. It means economy in greenhouse management if the ventilators of a house can be operated from one station located at its center.

Generally a 100-foot run is about the limit which can be operated from one place when the elbow arm is used. This can be increased with the double acting arm and still further, up to 200 feet, with the rack and pinion. In other words, one central station with two machines can be had to operate the roof ventilators on one side of the ridge for a house 200 feet long, using the arm elbow and either the perpendicular driving shaft or chain. This can be increased to one central station and two machines for the counterbalanced rack and pinion type in a house 400 feet long.

Most growers are inclined to feel the distinct advantage of operating short runs of sash (50-75 feet) so that the ventilation may be varied at different parts of the house as



House Equipped with Continuous Ridge and Side Ventilators
Note part stationary glass on side, sash joints covered with galvanized metal plates

needed. Furthermore, from a practical standpoint it has been found that since the torsion in the shafting is considerable in lengths of 75 feet, the sash do not open to the same degree along the entire run if more than this distance is operated on a gear.

In narrow, low roofed connecting houses for ridge and for side ventilation often no extra driving column or chains are needed, as the ventilators are within easy reach of the operator. In this case the hand-wheel and gear is fastened to the side posts, rafters or purlin posts. Then again, in such locations a short driving rod may be used.

Side ventilating machinery must be made so that it will not interfere with the use of the side benches or walks. The hand-wheel, gears and elbows must be made compact. The handle is made flat instead of long, as usual.

In a house with a side bench, a short driving rod is placed across the bench connecting the hand-wheel with the gears. In order to place this rod under the bench so it will not interfere with the plants, universal joints may be attached to it. These universal joints enable the driving rod to be bent in any direction and yet operate the ventilator. It means that the rods or driving columns can be so arranged that they can be operated from one walk. Extra columns are eliminated when universal joints are used. They are frequently used in conservatories.

Another system of ventilating apparatus occasionally used for operating long lines of side ventilators is what is known as the sliding shaft system. In this case the horizontal shafting is solid and square and it slides back and forth instead of rotating. The motion is given by a gear located at one end of the shaft. This sliding motion operates the sash by means of a right angle lever, pivoted at the angle with the short arm attached to the shaft and the long one to the sash. This system may be made to operate a line of sash or panel 200 feet long.

All ventilating apparatus should be kept well oiled and in repair. The ventilating arms or elbows may have to be readjusted after a time as they may get out of line, especially those at the farther end of a run of sash.

PAINTING AND GLAZING

All greenhouse woodwork should have a priming coat of pure linseed oil with a little white lead before leaving the factory. This protects the materials in transit and saves that much labor in erecting the house. Then as soon as erected the entire framework should be painted inside and out before glazing. Nothing is better than a mixture of pure white lead, linseed oil and zinc oxide with a little turpentine and dryer. After glazing another coat is applied, but care must be taken so that not more than 1/8 inch of the sides of the glass receives the paint. Otherwise unnecessary shading will result. The 1/8 inch covering seals the crack between the glass and the sash bars. If this protective paint covering is always maintained, water cannot enter at this critical place and cause decay and breakage of glass due to ice formation. Where pieces of wood are placed together the ends should be sealed with paint. All joints in the framework should be thoroughly coated with paint before being put together. A little lampblack may be added to soften the intense white for the outside of a greenhouse but pure white paint is best for the interior.

Due to the moist condition of air in the house, which favors the decay of wood, and to the difference of temperature between the outside and inside of the house which causes excessive contraction and expansion of the structural material, probably no other structures require as frequent or careful painting as do greenhouses. Thus heat, cold, rain, ice, fumigation and condensation all wear on the paint in greenhouses. As a rule, greenhouses should be painted inside and out every second year, and in places where excess

moisture is usually found, every year. This is the best insurance a greenhouse grower can have. Then the life of the greenhouse will be considerably increased.

Red lead paint is best for the first coat on iron work; after this the white lead will take hold. The iron work usually comes painted with red lead. After it is up, it should receive a second covering; then the white lead can be applied, one or two coats. What has been said regarding the painting of wooden members applies equally to iron members. Iron rusts readily and must at all times be protected with paint.

White lead and oil paints cannot be applied to the heating pipes because of the action of the heat. Aluminum radiator paint is excellent but too expensive. Paints which dry with a glazed surface interfere with the radiating properties of heat pipes. A mixture of lamp black and turpentine, to which linseed oil is added at the rate of one-fourth the bulk of the mixture, is good for this purpose. Graphite and linseed oil is used to some extent.

About one gallon of white lead paint should be figured for every 1500 square feet of glass surface for outside use, one coat; one gallon for every 750 square feet inside, one coat. It is best to buy the paint from greenhouse construction concerns as they have made a special study of greenhouse paint and have it available in three grades, one for the priming coat, one for the second coat and one for a third or last coat. It is needless to say that all paint should be thoroughly mixed and carefully brushed on.

GLASS AND GLAZING

Greenhouses today are generally glazed with double strength "B" quality clear American window glass. Double "A" grade is higher in quality but more expensive and not necessary. The standard sized glass used is generally 16 inches wide and either 18 inches or 24 inches long. It is

laid with lapped joints of 1/8 inch and spaced the 16 inch way between bars. Some favor the 16x18 inch glass because they claim it will not break as easily as 16x24 inch. However, it makes more laps and so the roof will not be as tight. One concern uses 18x20 inch glass, spaced the 20 inches between bars. This gives a wider spacing of the sash bars and therefore a lighter roof. Larger sizes of glass than those mentioned are too heavy and will slip down, making openings.

Sash bars are spaced 1/16 of an inch wider than 16 inches to allow for the glass. In setting the glass, it should be remembered that some glass is slightly curved. It should therefore be gone over and all the "rights" and "lefts" sorted out. The glass should be placed with the curve up, so that the joints at the laps will be tight. In this way the condensation runs to the bars and is carried to the eaves in the drip grooves in the roof bars.

Today much flat glass is used, but with flat glass and low-pitched roofs below 32 degrees the condensation naturally drops off at any place and does not work to the drip grooves in the bars. This may be somewhat offset by the fact that the laps will be tighter. Flat glass is almost entirely replacing the curved kind, and is easier to lay.

In the "butted" method of glazing, all the panes lie flat against the bottom of the grooves in the sash bars, and the lower edge of each glass rests against the upper edge of the one below. It is more difficult to make a tight roof with this method and roofs with a pitch of less than 30 degrees will leak badly if butted. The glass can be butted in the ends and sides of the houses for in this case the glass is perpendicular and dripping inside will not occur. Even here, however, the lapping method is preferred.

The laps should not be more than 1/8 to 1/4 inch, as otherwise there is likely to be more breakage due to the freezing of moisture between the panes. Dirt also collects underneath the laps where it cannot be cleaned and causes shade.

American-made glass is packed in boxes of 50 square feet each, a box of the 16x24 inch size containing nineteen lights; 18x20 inch size will come twenty lights per box; 16x18 inch, twenty-five lights per box.

In estimating the amount of glass necessary one must figure the number of square feet of glass surface in the greenhouse and divide it by 50 square feet to determine the number of boxes of glass necessary.

In the glazing of dwellings, the putty is placed on the outside of the glass in order to make a more pleasing finish, so that the brads holding the glass will not show. In greenhouse glazing, however, the putty is first rolled out in the rabbet of the sash bars and then the glass is pressed down onto it, thus sealing the glass to the bars. The excess is scraped off after the glass has set. The glass being firmly embedded in putty, rests on a sort of cushion and is not so readily broken by vibration.

The 16x24 inch glass is secured in place with ⅝ inch glazing nails, two directly below the lower edge of the pane to keep it from slipping down, then two about 2 inches from the end of the pane and two about the middle. Six nails or brads are thus required for each pane of glass. When glass 18x20 inches is used, placed 20 inches across the bars, the center brads are not needed. It is claimed these center brads cause cracking of the glass and so with this method less breakage may occur. With the butted method of laying the glass, generally two brads are placed about 2 inches from the top of the pane, two at the middle and two 2 inches from the bottom.

The sash bars used should have a tongue of at least 11-16 inch across, to hold two ⅝ inch glazing nails when placed opposite one another. If smaller than this the tongue is likely to split.

The modern angle iron eave is provided with special stops to keep the lower pane from sliding. Zinc strips

are not satisfactory because in time they wear soft and do not hold the glass.

The glazing of the roof should commence at one end of the house, starting at the eave and working toward the ridge. Then after several rows are laid, the excess putty can be scraped off. This glazing is best done on staging erected in the house which can be moved along as needed. However, on high and wide roofs it may be necessary to glaze the lower half of the roof, then move the scaffolding and glaze the remainder.

Liquid putty is sometimes used and applied with a rubber bulb or a glazing machine. Special liquid putty must be used in these, although standard putty can be thinned with pure linseed oil until it is thin enough to press out of the machine or bulb in a thin ribbon like toothpaste.

There is nothing quite so good as the putty made by the greenhouse construction concerns. It is made of heavy linseed oil and finely ground whiting mixed thoroughly and to be applied with a putty knife and the hands.

While there are several styles of glazing brads or nails, the best staple to hold the glass is the regular ⅝ inch glazing nail, made of zinc or galvanized iron.

In order to estimate the amount of putty necessary to glaze a greenhouse, one pound will reach about 15 feet alone one side of a glazing bar or 7½ feet along both sides; thus to obtain the number of pounds required, multiply the length of the bars by their number and divide by 7½.

Several putty substitutes and glass substitutes may be found on the market but they should be avoided. Use nothing but pure putty, and good quality glass. The substitutes will prove much more expensive in the long run.

BRACKETS

In reglazing the outside of the roof in greenhouses, a common means of supporting the workman is a 2-inch

plank supported by brackets. These brackets rest on each sash bar or every other one. They must be secured by nails or screws at intervals, just enough to hold.

Another means of support on the roof, used more for painting than reglazing, is a ladder made by nailing cleats on one side of a plank for foothold and longer ones on the other side so they will rest across at least two sash bars. The ladder is held in place by hooks which reach over the ridge. In small houses reglazing as well as painting can be done in this manner.

The Thompson Bar Painter is a special combination paint can and brush attached to a handle as long as necessary to reach to the ridge. It is designed to paint the roof bars on the outside in a much quicker and easier way than by the old method of climbing on the roof. It is calculated that from twenty to twenty-four 16 foot bars can be painted in an hour.

SHADING

During the summer months a shade is often required on the roof of the greenhouse to protect the crops from the intense sun.

In palm houses a permanent shade is maintained by the use of ground or frosted glass in the roof. Even then, however, when the sun is very intense this will not be enough to keep the plants from burning. Muslin curtains or slat rollers may be used inside the house to provide this protective shade. However, the usual way is to apply a liquid spray on the outside.

A good wash can be made of freshly slaked stone lime and water to which is added one part of common salt to four parts of lime. The salt should be added after the lime is slaked. This is then strained through a fine screen funnel and applied with a spray pump. It can also be applied with a long-handled brush, but with the pump it can be applied more readily and uniformly. This will probably have to

be applied two or three times during the summer. It comes off readily in the fall through the action of the rains and frosts and seldom requires scrubbing for removal. There is an objection to the use of lime, since it is injurious to paint. White lead and gasoline mixed to the consistency of thin cream is more permanent but may require scrubbing off in the fall.

Often a very temporary shade is required as when carnations from the field are planted in the houses, or when it is desired to hold back a crop of chrysanthemums when in bloom for Thanksgiving. For this purpose a thin mud wash made of soil and water can be thrown on the roof and will stay on until the next rain. One must be careful there are no large stones in the soil when making this mud wash.

Slat shading is frequently resorted to in orchid, fern and palm houses, especially on private estates and parks. It has several advantages, one of which is its neat appearance. Another advantage is that the shading is under complete control. On sunny days the shades can be let down and on cloudy days rolled up. The shades are operated by ropes running through pulleys.

BENCHES, BEDS AND WALKS

It may be said to begin with that most growers of cut flowers and ornamental plants prefer raised benches to ground beds. In the first place it is easier to take care of the plants when grown on benches than when on the ground. The use of benches also makes it possible to place heating pipes underneath them and this bottom heat means more winter production. There is also a better circulation of air about the plants when grown on benches, making them less subject to disease, and the soil is better drained.

On the other hand, benches are expensive to build and maintain. With crops such as sweet peas, tomatoes and cucumbers, not enough headroom may be available in the

averaged sized greenhouse if they were grown on benches. Therefore ground beds are used which are also cheaper to construct and maintain. Vegetable growers prefer ground beds and in large houses where lettuce, tomatoes or cucumbers are grown they are grown directly in the soil which forms the floor. In this case the house would be divided off into regular beds, divided by narrow walks and surrounded by a curb to keep the soil in place. Good drainage must be provided below the 6 or 8 inches of topsoil. Curbs of boards or planks are not satisfactory as they warp badly. A 4 inch concrete wall placed about 1 foot in the ground and 6 inches above the ground level, reinforced with iron rods, is best when a permanent curb is desired.

In order to strike a happy medium between raised benches and solid beds, some growers use raised beds. The height of these may vary from 1 foot to 2½ feet. In these the soil dries out less quickly than in benches. If cut flower crops are to be grown on them, only 5 to 6 inches of soil is necessary, the space below being provided with tiles for drainage or filled in with coarse drainage material. They may be built with wooden or concrete sides. Raised beds have not become very popular because they do not possess the advantage of economy of labor as in the case of ground beds and not as good cut flower crops can be grown in them as on raised benches, especially during the winter months.

The height and width of benches must be determined by the crop to be grown and the ease with which it can be taken care of. A bench too high would necessitate unnecessary reaching by the operator and one too low causes tiresome stooping. This is not efficient. A height of 30 inches from the walk to the top of the bench will be found quite satisfactory for the average person.

The width of the bench should also be determined by the distance one can reach conveniently in caring for the

plants. This distance is about 2½ to 3 feet, so that benches which can be worked from one side only should not exceed 2½ to 2¾ feet. Benches which may be worked from both sides should be no more than 5 or 5½ feet wide. As a matter of fact, narrower benches than these are generally used with such crops as carnations and roses, because in wide benches the central rows of plants suffer badly for lack of sunlight, air and attention and become diseased and neglected. Thus we find benches 3 feet 7 inches to 3 feet 10 inches wide for roses, accommodating four plants across the bench and 4 feet to 4 feet 4 inches for carnations, providing for five to six rows of plants across. These narrower benches produce better quality flowers. Cut flower crops require some means of wire supports and these limit the widths of benches for them, too.

In a pot plant house, side wall benches 30 to 33 inches wide can be used and the other benches may be 5 feet wide, as it is easy to handle the plants on a bench of this size. There are no supporting wires to interfere.

For cut flower crops side wall benches are not recommended, because the plants against the glass can be worked from one side only, making diseases and insects difficult to control. A walk is usually allowed next to the side walls.

The inside depth of most benches should be 6 inches so that they may contain soil to a depth of 5 inches. The bottoms should be provided with drainage apertures of about ½ inch wide and spaced about 8 inches apart.

In palm and show houses where potted plants are grown special plant tables are used with 2 inch sides, this being amply deep to allow for a coating of ashes or pebbles on which to set the pots.

Walks 18 inches wide are sufficiently wide for most houses, especially in commercial houses. Walks 2 feet wide ought to be allowed along the sides to give a little extra room for the heating pipes, usually placed along the walls

and for side wall ventilating apparatus. The central walk in the house should be a little wider, say 2 to 2½ feet, so that it will be a little easier to go through and a little more convenient for carrying purposes. Center cross walks and walks across the ends of the house should be about 2 feet wide. It must be remembered, however, that the walks should be cut down to a minimum for they do not produce profits. On the other hand, if they are too narrow, the house cannot be efficiently operated. In palm houses or conservatories wider walks will be necessary to accommodate more traffic and to keep persons from coming in contact with the palms and other plants.

The best material for walks in a commercial house is coarse coal ashes or cinders with the fine ashes screened out. These ashes should be kept away from pipes and other metal parts as the sulphur in them will cause corrosion. Concrete is best in conservatories where a neater walk is desired. It is not favored by commercial growers as it keeps the house too dry and also forms a breeding place for red spider.

Wooden benches are cheaper to construct than iron frame or concrete but are not as permanent. Many growers claim to be able to grow better crops on them. Common or pecky cypress is the wood most commonly used. The sides and bottoms of the bench are made of lumber 1 inch thick and about 8 inches wide. The bottom boards may be run lengthwise of the bench or crosswise. When lengthwise they are easier to shovel on but it is more difficult to make repairs as they must be nailed to the cross beams. When laid crosswise the boards need not be nailed and thus can be easily replaced. A space ¼ to ½ inch must be left between the boards to provide for drainage.

The size of the cross beams or stringers will depend upon the width of the bench and for benches up to 4 feet wide should be 2x4 inches, and from 4 to 6 feet should be 2x6

inches. The posts or legs are 2x4 inches or 4x4 inches, set about 4 feet apart, and should rest on concrete or brick piers. When cement walks are used the cement is carried far enough under the benches to act as a foundation for the posts.

In order to prevent warping of the side and end boards, angle or corner irons may be used in the corners and about every 4 feet along the sides, fastened by screws or small bolts. The wooden posts or legs may be made long enough to form a support for the side boards and thus prevent warping.

The wooden legs will usually outlast the bench bottom boards and cross beams as the latter come in contact with the moist soil causing decay. Wood preservatives such as "Carbolineum" or "Woodtex" may be used, being brushed on after the benches are built. A more thorough way would be to dip the parts in the heated preservative before erection. The bench should not be filled for 10 days to two weeks after such treatment. Heavy whitewash applied on the inside of the benches before filling with soil will aid in preservation also. Material for all kinds of benches can be had from construction concerns cut and fitted ready to nail together.

Iron frame benches with wooden sides and bottoms are much in favor although more expensive than those of all wood. The frames are practically indestructible and are made of 1 inch wrought iron pipe, tied together with split malleable iron castings, bolts and set screws. Galvanized iron frames supported by 1 inch pipe legs are likewise good. In combination with the iron frame benches, bottoms of iron, slate, tile or cement may also be used. These are not generally used except in conservatories because they are expensive. The cast iron bottoms with drainage holes will rust badly especially if ashes are used over them, the sulphur in the latter causing excessive corrosion. This interferes

with perfect drainage. The slate bottoms are often used for plant tables.

Benches may also be made having reinforced concrete legs. Homemade molds can be used for the forms or they can be purchased. These legs should be used about 4 feet apart. Cross beams of wood are placed on them and the remaining parts built of wood.

The use of concrete for bench construction is becoming increasingly popular, despite some impressions that they are cold and that chemicals in the concrete may injure roots. Their permanency is the great point in their favor, despite their greater first cost. Of course, it is not practical to ship concrete benches in parts and so they must be made locally. There are several firms having patents on concrete greenhouse benches who are prepared to sell or rent molds for making them or erect them complete. It is also quite possible for individuals to make their own forms. On the average bench, a mixture of 1 part cement and 2½ parts of coarse, sharp building sand should be used. This is reinforced with steel rods, approximately 3 inches apart. The bottom slabs are generally 2 inches thick, 6 inches wide and placed ½ inch apart. Posts 3½x4 inches are placed 4½ feet apart and set in the ground in a small footing of concrete. The parts are made separately and are interlocking.

Many growers are gradually replacing the wornout wooden benches with concrete. The parts can be made as time permits, generally during warm weather. Molds of heavy sheet steel with non-corrosive aluminum castings, suitable for making parts for 9 or more running feet of average width bench, can be purchased and because of their permanency can be used over and over again.

Wire frames for supporting wires used in growing cut flower crops, made of galvanized pipe and iron castings, are more sightly and durable than ordinary wooden supports.

CHAPTER VII

Heating Systems—Hot Water—Steam—Pipe Fittings

THE two systems of heating practical for greenhouses are hot water and steam. Hot water systems are generally used in plants of 50,000 square feet of ground space or under and for houses where coils would not exceed 200 feet in length. A hot water system is very simple and easily taken care of. It gives a mild heat that resembles sun heat more closely than any other known. It is more flexible than steam, requiring less attention and will keep heat longer between the firing periods. It is not so desirable for rose houses as the temperature of the pipes is not high enough to permit of burning sulphur or nicotine liquid in controlling mildew and insects. Where high temperatures are required it is not so desirable, for then it would be necessary to install an excessive quantity of pipes. Hot water is a safer system than steam and the care of it can be left to inexperienced help. It practically takes care of itself and it is not necessary to have a night fireman.

As to economy, while heating engineers disagree, it is the general opinion that hot water is just as economical as steam, provided either system is properly installed.

Due to the fact that hot water is easy to take care of and is perfectly safe for most anybody to handle, it is the best system for small plants. Its milder heat from the standpoint of the welfare of the plants, and therefore better heat, and less wear and tear on valves, unions, etc., are additional points in its favor.

In the larger greenhouse plants, above 50,000 square feet of ground space covered, steam must be used. Here the pipe lines are long and in plants of this size there is always

one house or more for roses, or for stock that requires a high temperature and an even control of heat. In a steam system, since the circulation depends on pressure of the steam, the piping can be run in almost any way you desire. Hot water systems depend on gravity circulation principally and so the pipes must be more carefully placed. The size of the mains for a steam system in a large plant are much less than for hot water. Thus for large plants the size of water mains would be extreme and undesirable. In a large place it is necessary to keep a night fireman anyway, who understands something about the greenhouse work, and so this is not an objection to steam heat in that an extra night man is necessary.

A steam system is undoubtedly the thing to install for the large plant. The steam may also be used to wash or sterilize soil, benches, concrete walls and walks. Then for medium sized commercial houses, the most practical heating system is the gravity steam heating system.

All rose ranges should be heated by steam, for the reason that a quick change in temperature does considerable damage to rose plants and with steam heat one can keep a more even temperature regardless of quick change in temperature outside.

It is well to suggest that in planning the heating system one should arrange for the future by installing mains and returns large enough to take care of future construction. This costs a little more at the start, but means considerable saving in the future.

The size and amount of heating pipe, as well as boiler capacity necessary to heat a certain greenhouse will vary with the size, location and kind of greenhouse. It is not practicable, therefore, to give specific information along this direction in a book of this kind. It is advisable to take this matter up with the greenhouse manufacturing concern when buying materials.

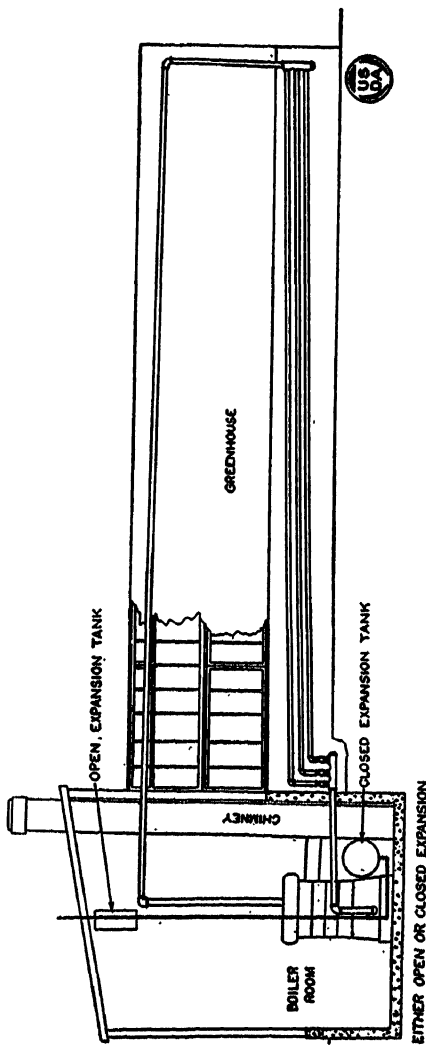


Diagram Illustrating the Principle of Hot Water Circulation

HOT WATER HEATING

The gravity hot water heating system with cast iron boiler, is particularly desirable for small houses and ranges up to 20,000 square feet of ground covered. Formerly 3½ inch cast iron pipes with packed joints were used, but due to leaking of the joints and cracked fittings, 2 inch wrought iron or steel pipe with screwed joints is now preferred. With a closed tank or pressure system and with a forced circulation, hot water systems may be efficiently used in ranges up to 50,000 square feet.

GRAVITY HOT WATER SYSTEM

The gravity hot water system works on the principle that hot water rises, and as it does, cold water takes its place. The boiler is placed lower than the heating pipes and as the water in it warms, it expands and rises through the flow pipe located at the top of the boiler, forcing the cold water ahead of it. It makes the circuit of the system and enters the boiler through the return pipes near the bottom. The average temperature of the water in the coils is 150 deg. F. The flow pipe is branched so as to provide the proper amount of radiating surface for each house.

The modern method is to have the highest point in the system immediately above the boiler, so that the water flows downhill for the entire distance through the house, as shown by the diagram. The pipes must be uniformly graded and short turns and bends must be avoided, so that the water will have an uninterrupted course through the entire system. Since water expands as it warms, and as the system is filled with water, it is necessary to provide an open expansion tank to take care of this increase in volume. This is placed at a point higher than the highest point in the system, generally in the attic or the workroom above the boiler but where there is no danger of freezing. It is best connected with the return pipe close to the boiler or

directly out of boiler, but should never be connected to coils, as the latter are not sufficiently supplied with water and the danger of emptying the expansion tank would thus be imminent. The capacity of this tank is generally about 1/20 of the capacity of the entire system. This capacity and proper size tank can be figured from the following table:

Capacity in gallons	Size, inches	Suitable for feet of 3½-in. pipe	Suitable for feet of 2-in. pipe
5½	9x20	250	750
8	10x20	350	1,050
10	12x20	500	1,500
12	12x24	600	1,800
15	12x30	750	2,250
18	12x36	900	2,700
20	14x30	1,000	3,000
24	14x36	1,200	3,600
26	16x30	1,300	3,900
32	16x36	1,600	4,800
42	16x48	2,100	6,300
66	18x60	3,300	9,900
82	20x60	4,100	12,300
100	22x60	5,000	15,000
120	24x60	6,000	18,000

Several methods have been devised to make the gravity hot water system more efficient. One is to use a closed expansion tank instead of the open one, having a capacity of about one-tenth that of the entire system. It must be airtight and fitted with a safety valve which is set to operate at 15 pounds pressure and will blow at 10 to 12 pounds pressure. It is connected with the heating system from the bottom of the boiler through the bottom of the tank. It may be located at any convenient point but no valves should be placed in the line connecting it with the boiler. Thus as the water expands it forces its way into the tank, putting

the entire system under pressure, by compressing the air in the tank. Through this means the water in the coils may be made to reach a temperature considerably above the boiling point. This system is good to care for a range of about 30,000 square feet of ground covered.

Another device designed to permit the hot water heating system to be more efficient is a mercury seal. It is designed to be placed in the pipe leading from the return pipe to an open expansion tank. This device is better than the closed tank with a safety valve, as it is less likely to become clogged and stick than the safety valve. In principle, the water, by heating, must reach a pressure great enough to force up a column of mercury before the water can enter the expansion tank. This automatically keeps the pressure at any predetermined point, usually about 10 pounds, and makes it possible to heat the water to a temperature of 240 degrees F. It helps sluggish circulation and makes the water travel three to five times faster. The faster it travels through the system, the less heat will be lost and less fuel will be required to again circulate the water. It also prevents boiling over of the water as is the case when just an open tank is used. It should be near the boiler on a separate line from boiler to tank. This device enables one to obtain steam temperatures in the pipes and yet have the advantages of a hot water system. It makes it possible to heat the coils to a high temperature in severe winter weather and at the same time permits the system to be run at lower temperatures in mild weather. If a given gravity system is sluggish, it might be advisable to install this equipment.

A forced circulation hot water system improves the system so it may efficiently heat ranges up to 50,000 square feet. Pumps are used to circulate the water through the mains and radiating pipes. The general arrangement of the pipes is the same as for the gravity system, except that the

mains and radiating pipes may be run level if desired and no deep boiler pits are required. The pump may be either of the rotary or centrifugal type, and it may be operated by an electric motor, a steam engine, or gas engine. In cases where high pressure steam is available a direct acting steam pump may be used. In small plants, however, this steam would not be available.

HEATING COILS—HOT WATER

In the heating of greenhouses all parts of the houses must be kept at a nearly uniform temperature. Radiators, such as are used in private houses, are not good in greenhouses to get this even distribution of heat. Long coils of wrought iron or steel are used instead. In hot water heating 1¼ inch pipe to 2 inch pipe is used and for steam heat 1 inch to 1¼ inch pipe is common. As stated before, the large size cast iron pipe of 3½ inches diameter with packed joints is not used commercially but occasionally in small private conservatories. The first cost is too great, and if installed by the owner, a proper installation is hardly ever accomplished. The smaller wrought iron pipe is lighter and much more easily handled. It is screwed together and can be placed along the side walls or hung on the supporting posts instead of having to be supported by masonry piers as in the case of large cast iron pipes. Two inch pipe is commonly used for hot water, and 1¼ inch for steam.

In general the heating coils are placed in horizontal runs, along the side walls of the house, under the benches, or along the sides of solid beds. The heating coils are made by joining the several pipes together, along the side walls for example, by means of headers or manifolds.

The pipes along the side walls tend to warm the cold air that enters at the sides through the glass crevices. It is generally best to place more pipes along the north wall of a house running east and west than along the south wall, to

take care of the extra cold there. The pipes come in random lengths from the factory, the average being about 20 feet.

In a hot water system the flow pipe leaving the top of the boiler is carried vertically to a point high enough overhead to insure ample fall for the pipes to make the circuit of the houses and return with uniform grade through the return pipe at the bottom of the boiler. This flow pipe is often carried just below the ridge of the greenhouse and for large plants would be placed from 10 to 15 feet from the ground. The overhead flow pipe branches into the returns, which are the heating coils, at the end of the house away from the boiler. The heating coils grade down toward the boiler and at the end of the house nearest the boiler are connected with a header which in turn empties into the return pipe to the boiler. There is some objection to the flow pipes overhead in a greenhouse as they cast shade, but this is not serious. If the boiler is low enough, the flows may be placed in conduits under the walks, using the "uphill" system, the flow rising gradually until it reaches the coils at the end of the house farthest away from the boiler. The coils then pitch down toward the boiler. The pipes must be uniformly graded, having a fall of 1 inch to 20 feet to insure good circulation.

Where several houses are heated, a common header is supplied by the main flow pipe and runs along the ends of the houses, preferably in the potting shed or workroom. This pipe is gradually reduced in size in accordance with the amount of radiation supplied for each house. A common return pipe is usually located underneath the floor and this is gradually increased in size as it nears the boiler to its full size at the house nearest the boiler.

When branching hot water pipes, sharp turns should always be avoided. Each turn retards the flow of the hot water, therefore the pipes must take the most direct route to each junction.

The overhead flow pipes should be supported every few feet by pieces of chain or regular pipe hangers to prevent sagging. These are fastened to the purlins or rafters. When the flow pipes are carried in conduits, they rest on rollers. It is better to have two flow pipes suspended from the interior supporting posts, than one large heavy one suspended from the ridge.

The radiating pipes on the side walls or center posts are carried on pipe hooks, and those under the bench rest on the bench supports. Each pipe line in the system should be fitted with a gate valve so it can be turned on or off as necessary. These valves may be placed either in the flow or return pipes, or both. If a valve is placed in both the supply and the return end of each coil, any pipe may be repaired in case of an accident, without interfering with the circulation of the other coils. Gate valves are used in hot water heat to allow a wide opening. Also an automatic air valve should be provided to keep the system free from air at the highest point in the flow pipes.

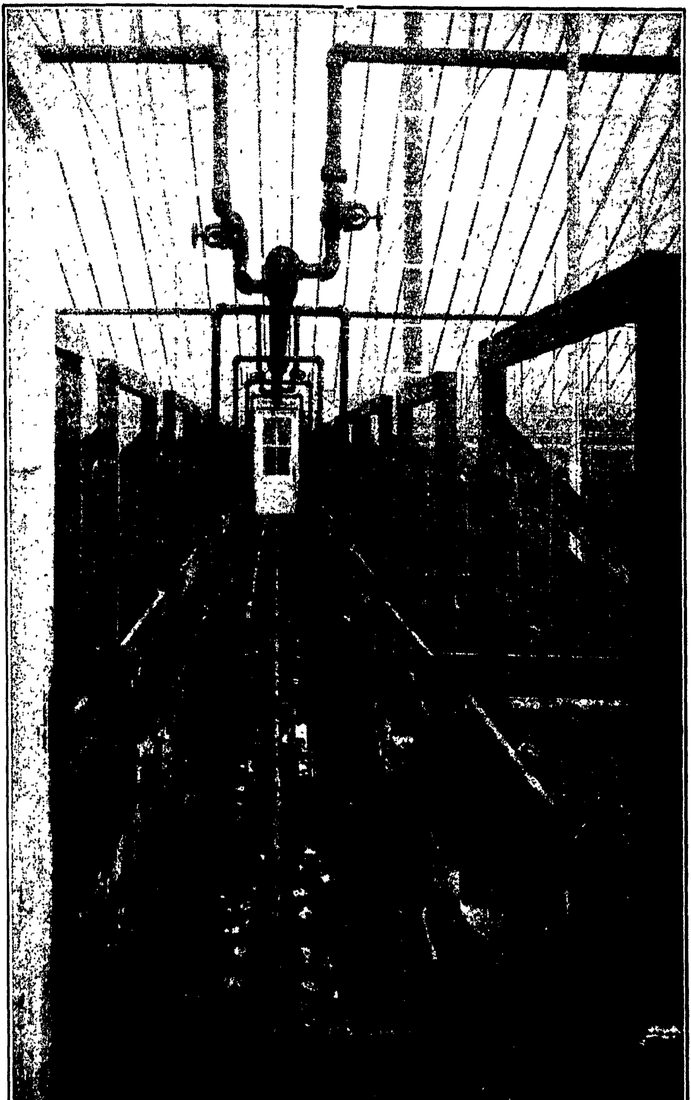
The length of coils and sizes of pipe which are used for gravity hot water heat is as follows:

Size of pipe	*Length of coil*
1 inch	Up to 50 feet
1¼ inch	50 to 75 feet
1½ inch	75 to 100 feet
2 inch	100 to 150 feet

When forced circulation hot water heat is used the length of pipe may be increased about 10 per cent.

STEAM HEATING

In steam heating systems there is not the circulation as in the case of hot water, but steam is conducted through the heating coils and travels due to energy. In the coils the steam condenses and gives up its latent heat. This condensation returns to the boiler by gravity, flowing back through



Steam Installation in 62 Feet Wide Rose House
Mains overhead, returns under cross walk

the supply pipes or through return pipes as in the case of hot water. This latter system is most commonly used for greenhouses. In fact the low pressure gravity steam heating system is best for medium sized ranges, from 50,000 square feet of ground covered to 100,000 square feet.

The low pressure gravity steam system may be called fool-proof because there are no traps and pumps to get out of order. The pressure of steam used is from 4 to 8 pounds and 5 on the average. The boiler is placed in a pit deep enough so there will be a 24 inch drop from the return to the water line in the boiler. The return water then flows back by gravity directly into the boiler.

Steam mains may be placed overhead or in a trench with "bleeders" to carry condensation. Thus in steam systems the objectionable overhead mains may be eliminated, but in actual practice commercial houses often have overhead mains with the highest point above the boiler, and flow down hill. This saves extra digging and placing the boiler in a deep pit. If the steam mains are in a trench, the boiler pit must be dug deeper. These overhead steam mains should be covered with asbestos.

In coils over 200 feet long, it is advisable to put in a valve in each pipe at the low end of coil.

In the heating of very large ranges of greenhouses the most practical system of heating is what is called the vacuum steam system. In installing this type of heating the boilers are placed on the same grade as the greenhouse and this eliminates digging pits for boilers. This is a high pressure heating system generally carrying about 80 pounds pressure at the boilers. The high pressure mains are extended out to the greenhouses and a reducing valve brings the pressure down to 5 pounds before entering the houses. Then from these low pressure mains the steam is carried to the coils at the sides of the houses and under the benches, the flow end being in the center walk. At each end of the

STEAM HEATING SYSTEM
Mains under cross walk. Heating pipe with swing expansion joint on each side of bench

house these coils are connected to vacuum traps. The condensation travels by gravity to these traps, and as soon as traps fill, they automatically dump themselves. They are connected directly to a vacuum tank in the boiler room which is filled by this condensation. This tank is connected to a vacuum pump, which automatically keeps a

vacuum in the tank and then on the other side the tank is connected to a boiler feed pump. This vacuum tank also works automatically, for as soon as the water rises to a given height the mechanism starts the boiler feed pump and the water is pumped into the boiler.

In any steam system it is necessary that the pipes be kept free from air. In the vacuum system this is automatically provided. In the gravity steam system this is accomplished by either automatic valves such as the Hoffman Automatic Air Valve or by hand-operated valves. It is best to have an air valve at the low end of each coil in the header, in the gravity steam system.

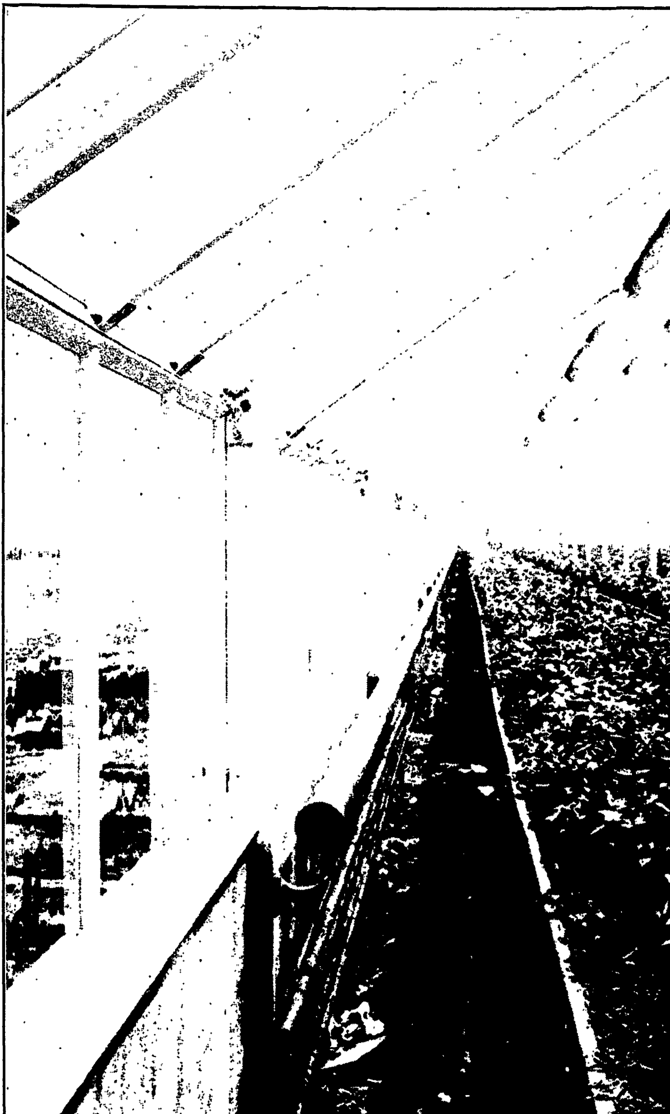
STEAM HEATING—COILS

The heating coils for the steam system are smaller sized than those for hot water. The temperature of the pipes is higher and so less radiation is necessary to maintain a given temperature. Wrought iron or steel pipe 1 to 1¼ inch need only be used for the coils, the 1¼ inch being most common.

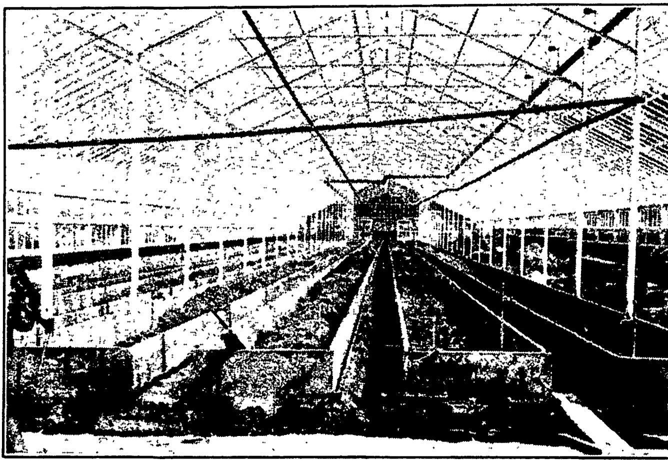
Size of pipe	*Length of coil*
1 inch	75 feet
1¼ inch	150 feet
1½ inch	250 feet

Two or more comparatively short coils will give better results than one which is excessively long. In a small house it is possible to run the coils entirely around the house, giving them an even downward slope.

In one method of arranging the coils, the condensation is carried back to the boiler through the supply pipe. The pipes all have an upward slope from the boiler, being careful there are no sags or pockets in which water can collect. In short runs this method may be used but in long runs due to the interference of the steam and return water there will be much hammering in the pipes. In dwelling houses, where



Steam Heating System
Main carried just above heating pipes



Concrete Raised Beds
Note steam pipes on each side of bed

the supply pipes are vertically placed, this system is satisfactory.

The most satisfactory method for greenhouses is to arrange the steam pipes similar to those for hot water heating. The flow pipe is placed overhead and goes to the farthest end of the house, then branches down to the coils, which are graded 5 inches per 100 feet toward the boiler. The condensation runs in the direction of the steam, and collects from the coils in the header, passing back to the boiler through a return pipe. This return pipe then enters the boiler below the surface of the water. The return pipe can be slightly smaller than the flow pipe, usually about ¼ to ½ inch smaller.

Pipe expands about 1½ inches in every 100 feet when heated from ordinary temperatures to that of steam and provision must be made for this expansion. Either swing joints or telescoping expansion joints are used to take care of this, being placed in each pipe, generally at the further

end of the house. For this reason also, the mains and coils must not be fastened rigidly to the house but must be supported by hook or roller carriers. To control the direction of this expansion and contraction movement it is necessary in long runs to anchor them at certain points.

EXPANSION OF WROUGHT-IRON PIPE ON THE APPLICATION OF HEAT

Temperature air when pipe is fitted	Increase in length in inches per 100 feet when heated to							
Deg. F.	160	180	200	212	220	228	240	274
0	1.28	1.44	1.60	1.70	1.76	1.82	1.92	2.19
32	1.02	1.18	1.34	1.44	1.50	1.57	1.66	1.94
50	.88	1.04	1.20	1.30	1.36	1.42	1.52	1.79
70	.72	.88	1.04	1.14	1.20	1.26	1.36	1.63

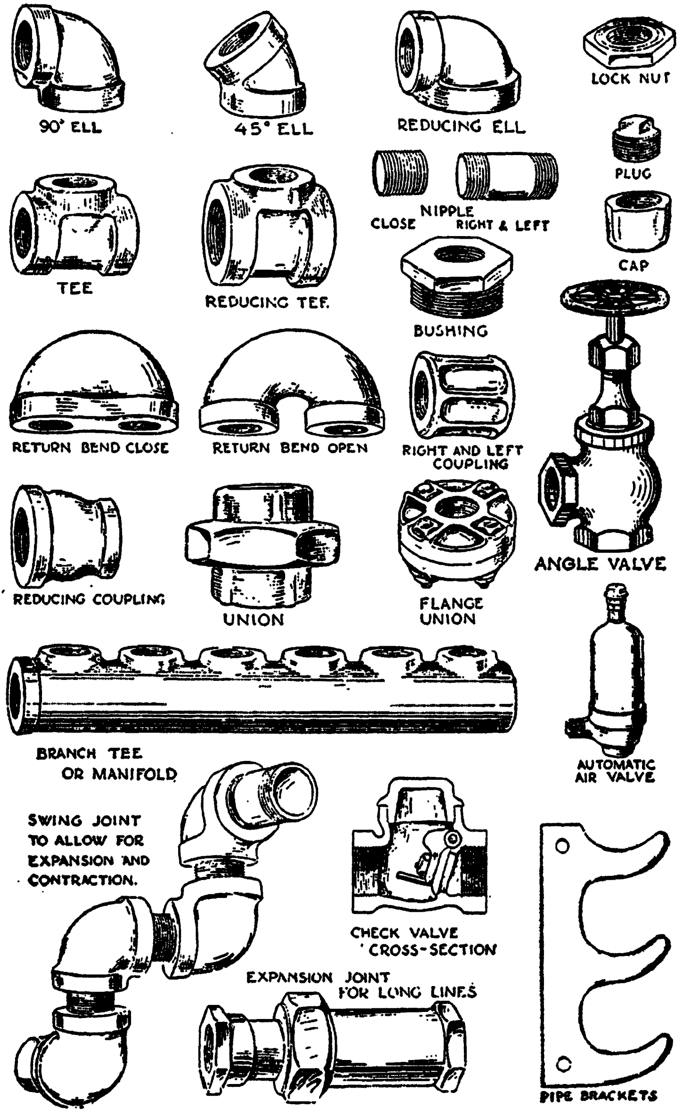
CROPS GROWN ON GROUND LEVEL
Note heating pipes on rafter posts

It is essential with steam heating that each coil be provided with a valve so it can be shut off when not needed. This should be a check valve or globe valve placed at the return connection of coil. All globe disc valves should be used in steam heating and not gate valves as in hot water heating.

PIPE FITTINGS FOR STEAM AND HOT WATER SYSTEMS

The following information on greenhouse pipe fittings is given through the kindness of Mr. James H. Beattie of the United States Department of Agriculture.

"Here are illustrated some of the more important parts and fittings for steam and hot water heating systems. The use of these fittings is well understood by most steam fitters, but some of them have been designed especially for greenhouse work. Either 90-degree, 45-degree, or reducing ells are employed where it is necessary to make turns in the direction the pipe is being carried. Right-angle turns are to be avoided wherever it is possible to use pipe bends or 45-degree ells. Reducing ells are seldom used in hot water systems but may properly be employed in the return lines of steam systems. The same is true of reducing couplings. Tees must be employed where it is desirable to take two lines from one pipe, but in hot water systems they should be so used that the supply is not attached to the fitting on the side of the tee, as the current of water is retarded when it strikes the side of the tee. The supply from the boiler should be attached at one of the end fittings of the tee, using the other two for the branches. The right and left threaded coupling with the right and left threaded nipple and a lock washer are employed in some cases instead of an ordinary union or a flange union. Bushings have a very limited use in heating work and should be employed only where their use is absolutely necessary. It is far better to use reducing



Some of the fittings used in the steam and hot water heating systems of greenhouses

couplings, but the best method of all is to plan the system so that reducing tees can be employed in branching the lines, thus avoiding the necessity for employing either bushings or reducing couplings. Plugs and caps are properly employed only for the purpose of temporarily closing lines where extensions are to be made. Return bends are much employed for the making up of coils of pipe for installation on walls where the pipe is only a few feet long. The open pattern is to be preferred where sufficient room is available for its use.

"For greenhouse work the ordinary ground joint threaded unions are used for small-sized pipe, but for pipe above 2 inches in diameter the flange union is usually employed. Right and left couplings are employed for moderate-sized pipe, but these are seldom used for pipe larger than 2 inches. Branch tees are used where it is desirable to install several lines of radiating pipes in close proximity to each other, such as on the side walls of the house between the floor and the ventilator sash. These tees cannot be used on both ends of long lines of pipe unless expansion joints are installed in each of these lines, as unequal expansion caused by some of the lines being hotter than the others will cause breakage. A method often followed to overcome this is to use one of these branch tees at one end of the radiating pipes, locating it so that the coils can be carried to a corner of the house where right and left hand ells are used to make the turn and running along the end of the house to a door where another branch tee is employed. The expansion of the pipe is cared for without placing a strain on the branch tees, but care must be taken to have the pipes far enough from the corner so they can move freely. The tee at one end of the line, usually the one near the door in the end of the house, is connected to the supply from the boiler through the tapping in the end of the tee, while the other tee is connected with the return system. Each radiating line should be fitted with

a valve of the type best adapted to the conditions. The one shown in the illustration is known as an angle valve, but other types are available. Every set of radiating pipes, whether for steam or hot water, should be fitted with suitable means for removing air from the system. Such valves should be at the highest point in the system in which they are installed. Check valves are used in the return lines of steam systems to prevent the condensation from backing up in the system."

CHAPTER VIII

Boilers—Operation of Hot Water Boilers—Operation of Steam Boilers—Chimneys—Boiler Rooms

GREENHOUSE boilers are made of cast iron, wrought iron or steel.

Cast iron boilers are more commonly used in heating ranges up to 30,000 square feet. They are made in sections so that they can be increased in size up to certain limits as more heat radiation becomes necessary. The two general types of cast iron boilers are the round horizontal sectional and the square vertical sectional. They are made for either hot water heat or steam. The sections are joined together by push or screw nipples and section cement. The round horizontal sectional boilers are used for small houses and the square vertical sectional boilers for the medium-sized ranges. Sectional boilers are easy to ship and handle and are useful where frequent additions are likely to be made to the greenhouses.

Wrought iron or steel boilers are used in large ranges, 100,000 square feet and over, being of the so-called tubular type. In one type the burning gases pass around horizontal tubes which contain water. This is the water-tube type. In the Scotch Marine tubular boiler, these burning gases pass through the tubes which are surrounded by water. This is called the fire-tube type.

In the gravity system of heating the boilers must be below the level of the coils and mains. When they cannot be so located, special traps and pumps must be used to return the condensation to the boiler. Steam, gas or electric motors are used to operate these pumps.

Two Sectional Hot Water Boilers in Battery

For hot water boilers an altitude gauge should be attached which shows the height of the water in the system and also a thermometer to show the temperature. A gate valve is provided to drain the boiler.

For steam boilers, since they are only partially filled with water, a water column and gauge is necessary to indicate the height of the water. A steam gauge which shows the pressure and a safety valve to relieve the pressure automatically if it becomes too great for safety are necessary.

Automatic damper regulators may also be provided, but are more efficient on steam boilers than on hot water boilers. They are not used much in hot water heating.

It is best to purchase a boiler especially designed for greenhouse heating. Their ratings are figured in the amount of linear feet of certain size pipe they can heat, or the amount of square feet of glass or glass equivalent they can heat, or as in large boilers, are rated in terms of horsepower. They develop heat enough for 100 square feet of radiation per horsepower. Boilers rated for ordinary dwellings would not provide the heat claimed for them if used for greenhouses, as the latter are more difficult to heat because of less resistance to the penetration of cold. Their ratings should be discounted 20 per cent if used for greenhouses.

Cast iron sectional boilers should be covered with asbestos to prevent loss of heat. A granular form of asbestos which is mixed with water and applied with a trowel and the hands, is generally used for this purpose. All heating mains and returns in cellar and outside of greenhouses, should be covered with molded asbestos casings which can be had to fit all sizes of pipe.

When the amount of pipe of a given size necessary to heat the house or houses is known, the boiler can then be chosen which will supply this heat. As a rule, a boiler having a rating of 20 to 25 per cent more than the amount of heat needed is desirable. This will allow for differences

Large Steel Tubular Steam Boiler—150 h. p.

in fuels and poor drafts and will not make it necessary to fire the boiler very hard in extremely cold weather.

For soft coal it is desirable to use a shorter, wider boiler than for hard coal. It is advisable to add one section more than would be required if hard coal were used. Also, a larger grate surface is necessary for soft coal as it cakes together and the draft cannot get through it as easily. It also requires more boiler surface because the soot of soft coal is more difficult to get off than the dust from hard coal and soot prevents to an extent the passage of heat to the water.

The ratings of hot water boilers are based on the assumption that the average temperature of the water in the coils is 150 degrees F. and about 180 degrees F. at the flow connection. Where steam is used, the rating is based on 2 pounds pressure at the boiler.

The following instructions regarding the operation of boilers are given through the kindness of Hitchings & Co.:

OPERATION OF HOT WATER BOILERS

"*To Fill*—To fill the apparatus, open feed cock, and see that all air cocks are opened and left open until coils are filled with water. (If automatic airvent headers are used, they will vent the coils automatically and close when the coils are filled). When the coils are filled, close the air cocks and let the water run until it shows about 3 or 4 inches in the gauge glass of the expansion tank. After the water is heated, vent the coils again by opening the air valves as before, and if the water does not show in the gauge glass, turn on the feed again until 3 or 4 inches show.

"*To Empty*—To empty the apparatus, open the draw-off cock, which is located at the bottom of the boiler, as well as the air cocks and valves on all coils.

"*Keep Full of Water*—Always keep the apparatus full of water, unless the house is not used during the winter months, when the water must be drawn off to prevent freez-

ing. Never draw the water off while there is a fire in the boiler. Never start a fire until the system is full of water.

"*To Start Fire*—Open damper in smoke hood and draft in ash pit door. When fire is well under way, regulate dampers to give heat conditions desired.

"*Firing*—Economy of fuel is effected by careful attention at regular intervals, not neglecting fire until the temperature of the house has fallen. Keep the fire pot full of fuel and evenly distributed, regulating the fire by the different dampers. Open slide damper in fire door when fresh coal is put on, so as to admit air for better combustion, until fire is burning brightly. Always keep a clean fire, removing ashes by means of shaking grate. Remove ashes from ash pit frequently. If allowed to accumulate, there is danger of burning out the grate bars. *This is the only way grate bars will burn out.*

"*Care at Night*—In preparing boiler for the night, clean the fire well of ashes, and fill fire pot with coal, regulating damper so as to keep fire until morning. Experiment with dampers in different positions until the results desired are obtained.

"*Cleaning*—To have an efficient heating apparatus, it is of importance that the flue surfaces should be kept free from soot and ashes. Clean these frequently through clean-out doors.

"*To Remove Grates*—Remove shaker handle and connecting bars. Rock grate backward, until round part on right end of grate is on top. Lift up right end of grate as far as possible, and push back until grate drops.

"*To Put in New Grates*—Place left end of grate in socket. Rock backward until round part on right end of grate is on top. Lift up as far as possible and bring forward until grate drops in socket. Attach connecting bars and shaker handle after all grates are in position.

"*End of Season*—At the close of the heating season thoroughly clean all of the surfaces of the boiler, remove the smoke pipe and store it away in a dry place. Leave all boiler doors open, and oil the hinge pins of all the doors. At the opening of the season, withdraw the water and fill with fresh water, starting the fire as before.

OPERATION OF STEAM BOILERS

"*To Fill*—To fill the apparatus, open feed cock and allow water to run into boiler until water line is shown to be of proper height in water column. First see that all valves on the system are wide open.

"*To Empty*—To empty the apparatus, open draw-off cock which is located at the lowest point of the system.

"*To Start Fire*—Open damper in smoke pipe and draft in ash pit door. When fire is well under way, close draft in ash pit and regulate damper in smoke flue to suit conditions. *Start fire slowly.*

"*Firing*—Economy of fuel is effected by careful attention to the fire at regular intervals, and by not allowing the fire to go until the temperature of the house has fallen. Keep the fire pot full of fuel and evenly distributed, regulating the fire by the different dampers. Open slide damper in fire door when fresh coal is put on, so as to admit air for better combustion, until fire is burning brightly. Always keep a clean fire, removing ashes by means of shaking grate. Remove ashes from ash pit frequently. If allowed to accumulate, there is danger of burning out the grate bars. This is the only way grate bars are burned out.

"*Care at Night*—In preparing the boiler for the night, clear the fire well of ashes and clinkers. Fill the fire pot with coal, regulating dampers according to the heat required. For dwelling heating, the dampers can be regulated so that the fire can be kept over night without attention. Experiment with dampers in different positions, until the desired

results are obtained. To properly take care of a greenhouse plant when heated with steam, it is necessary that the fire be given attention at frequent periods throughout the night.

"*Cleaning*—To have an efficient heating apparatus, it is of importance that the flue surfaces should be kept free from soot and ashes. Clean these frequently through clean-out doors with brush, which is provided with every boiler.

"*To Remove Grates*—Remove shaker handle and connecting bars. Rock grate backward until round part on right end of grate is on top. Lift up right end of grate as far as possible, and push back until grate drops.

"*To Put in New Grates*—Place left end of grate in socket. Rock backward until round part on right end of grate is on top. Lift up as far as possible and bring forward until grate drops in socket. Attach connecting bars and shaker handle after all grates are in position.

"*Regulating*—The damper regulator will control pressure of steam, closing damper when pressure is raised beyond a certain point, and opening it when pressure falls below the point. By adjusting weight on lever, different degrees of pressure can be maintained.

"Allow nothing to interfere with the lower draft door to prevent it from closing tight with the action of the damper regulator.

"*Water Line*—Examine the water glass regularly to see that the water line is at the proper height, viz., gauge glass about one-half full. If lower than this, open the supply valve until the correct water line is secured. *If at any time it should appear that the water is all out of the boiler, immediately dump the fire, remove from ash pit and allow the boiler to cool off before attempting to fill with water.*

"*End of Season*—At the close of the heating season, thoroughly clean all fire surfaces of the boiler, also draw off water and refill boiler to top. At the opening of the next

season, withdraw the water and fill with fresh water to water line, starting the boiler as before.

"*Safety Valve*—Lever of safety valve should be pulled down occasionally to see if it is working properly."

Two or more boilers may be connected in battery so that both of them or either one may be operated independently to heat the range. In the early spring or late fall it is not necessary to start an immense boiler to heat the houses when a smaller one will give as much heat as needed. Boilers in battery give complete control over the heat as well as the coal burned.

Then too if a grower has only one large boiler, he has nothing to rely on in case of a breakdown. When two or more smaller ones are in battery, one may be repaired while the other one or more can be fired harder during this time.

It is advisable when possible to deepen the ash pit of the boiler, either by making a raised foundation under the boiler, or by excavating and making a brick sub-pit. This will allow better draft and so improve combustion. In addition it will prevent the burning of the grate bars due to accumulation of ashes. Boilers in general should be covered either with asbestos or brick.

CHIMNEYS

Poor chimneys are one of the chief causes for failure of the heating apparatus. The area of the flue should be of ample size to carry off obnoxious gases, and the chimney should be carried as straight as possible. It must be of the proper height to produce the proper draft. A chimney for steam or hot water heating should have no other opening than that used for the heating apparatus.

Round chimneys are most effective as the draft in a chimney is spiral. The height should be great enough to prevent the possibility of interference with the draft by surrounding buildings, trees or the roof of the building of

which the chimney forms a part. The inside surface should be smooth and all the joints tight. The lower part of the chimney should extend several feet below the entrance of the smoke pipe and should be provided with a clean-out door at the lowest level for the removal of accumulated dust and soot.

The boiler should be set as near the chimney as possible and the smoke pipe must not project into the chimney beyond the inside of the flue, as this will lessen the draft. A new chimney will not draw properly for a few weeks until it has dried out.

Chimneys are most commonly built of common brick lined with flue lining made of fire clay. A special perforated radial brick is often used; this requires no special lining. They may also be built of steel cylinders.

Boilers are usually provided with a smoke pipe opening large enough for them and if a chimney is built with the same size flue it will be large enough. However, chimneys should be large enough to take care of future boilers.

BOILER ROOMS

Since the heating plant is the "heart" of the greenhouse range, the boiler room should be as nearly centrally located to the glass as possible. In choosing the location consideration should be given as to the direction in which additional glass houses will be erected. Often a natural slope may be taken advantage of in locating the place for the boiler room. This will give the boilers a lower location than the heating mains and coils for the houses, and a simple gravity system can be installed. This saves the necessity of excavating.

In general practice today the boiler room is located on the north side of the range, or in the center of it, with greenhouses to north and south. This boiler room should be built large enough to take care of present needs for the

boiler or boilers and some coal storage as well. It is probably good policy to build the room about twice as large as necessary at first to allow for additional boilers. One way of providing for the future is to build a temporary end so that an extension may be added in the future.

Modern boiler rooms are being built of concrete foundations, floors, and walls, and steel frame superstructure, similar to greenhouse framework. These are fireproof. The concrete may be carried about two-thirds of the way up the sides and ends and the upper portion built with glass sash and ventilators. The roof is covered with corrugated metal roofing. This provides for a substantial fireproof and light airy room.

Concrete blocks are frequently used, as well as brick. When the boilers must be placed in a pit, this should be built of concrete, about 12 inches thick. This should be waterproof on the outside, as should all boiler room foundations or cellar walls. Hot coal tar pitch or cement plaster should be coated on the outside, before the soil is banked against the walls. Tile drains should also be provided about the outside to take away the water.

The boiler room should have sufficient air circulation to supply ample air for combustion. If a boiler is set in a small or tightly closed cellar, the lack of air supply to the grate may prevent active combustion.

The workroom or headhouse is usually built next to the boiler room. This may be divided into a space for potting plants, an area for packing cut flowers and plants, a refrigerator for the cut flowers and the office.

CHAPTER IX

Fuels—Oil as Fuel—Water Supply—Capacity of Tanks

COAL is the most universal fuel used for greenhouse heating, although oil is being used to a considerable extent today. In the natural gas and oil districts of the middle west and south gas is used. Special burners must be placed in the boiler to burn oil or gas fuel. With gas the pressure is likely to be lowest in the coldest weather, which is undesirable as then the most heat is needed. It is, however, an ideal fuel. Oil likewise is ideal as a fuel, but a steady supply must be available. Hard wood may be used but requires more attention.

Coal is of two general kinds, hard coal or anthracite, and soft coal or bituminous. Hard coal burns with little smoke and is a cleaner fuel than soft coal. It is easier and cleaner to handle, requiring less attention in firing, but is usually more expensive. It is better for the small grower who has a hot water heating system and does not keep a night man. The fires can be banked at night and will keep well until norning.

The soft coals are of two general types, the coking or semi-bituminous and the free burning. The former fuses together in burning and is more difficult to handle than the free burning, but is preferred by some growers.

Firing should be done regularly and at short intervals, either placing the coal at the sides of the fire, afterward to be turned into the middle when red, or placing it in front and pushing back when well aglow. If the entire firebox is covered at a time with fresh coal, the fire will be banked and the temperature of the hot water or steam will drop,

causing a consequent drop in temperature in the houses. With soft coal the boilers should be fed every hour during cold weather. A night man is necessary to look after the proper handling of the fire and he should record the temperatures in the various houses several times during the night.

It is generally agreed that 7 to 10 tons of soft coal are necessary per 1000 square feet of glass area to maintain a temperature of 60 degrees F. for a seven-months firing season beginning with October. For hard coal about 6 to 8 tons will be consumed during this period. These amounts will of course vary according to locality, heating system and grade of coal used.

Pea coal, buckwheat, rice coal and screenings or slack, which are cheap fuels, may be burned with the aid of a blower, creating a forced draft. This fanlike blower is attached to the side of the ash pit and is operated by steam or electricity.

Coals vary in the number of heat units per pound given off according to the source of mining. Their price is based on this rating as to the amount of British Thermal Units or heat units contained.

OIL AS A FUEL

Fuel oil is taking the place of coal to a great extent wherever the facilities for obtaining oil in quantity exist. In terms of British Thermal Units, 150 gallons of oil are about the equivalent of one ton of a good grade of bituminous coal, and 120 gallons are equal to one ton of anthracite.

There are various kinds of fuel oils on the market today but light grades are most commonly used. That used in house heaters or small places is a light oil called "Domestic Oil," while that used on a large scale is a heavy black oil. All the fuel oils come from Mexico and are derived from petroleum, varying some in composition. The heavy oils

must be heated before burned while the light oils, similar to kerosene, need not be. The latter are preferred for this reason.

Oil, like gas, is considered a perfect fuel, as it is nearly completely burned and no unburned gases escape up the chimney as is the case with coal. The boiler efficiency when coal fired averages 65 per cent, with fuel oil 80 per cent. In most sections gas is out of the question as a fuel because of its high cost. Only in natural gas regions, such as in Ohio, is it economical to burn.

There are numerous advantages of the oil heating systems over coal heating, namely, there is a more perfect combustion, more equal distribution of heat, practically no deposit of soot to retard the heat flow, more uniform rate of combustion, no excess air such as enters the furnace in stoking coal and cleaning the fires, absence of dirt or coal dust, no dirt in stoking or cleaning fires, no removal of ashes, with consequent cost of haulage and labor, only a few minutes are required for lubricating the oil-burning equipment and for lighting the fire, no banking of fires is necessary as fire may be turn off or on as needed, heat may be procured more quickly, saves labor, only one man being needed in place of several, saving of storage space. A ton of coal occupies 43 cubic feet, whereas the equivalent in oil value occupies only 20, therefore the oil requires 50 per cent less storage space. Oil may be located at some distance from the boiler without inconvenience. Disadvantages of the oil systems may be given as the comparatively high price and unpleasant odor.

There are four considerations to an oil burning system. These are the oil storage, necessary means of atomization, oil burners, and modifications of the boiler.

The oil is stored in concrete or steel tanks which may be under or above ground; the former is preferred. Where tank wagon delivery only is available a tank of 500 gal-

lons upward should be employed. In cases where tank car deliveries are obtainable a tank of not less than 10,000 gallons should be supplied. Duplicate tanks are desirable as sufficient oil should be stored to provide for emergencies. The oil is pumped from the tank through an underground pipe to the burners. Previous to burning, the oil must be broken up finely into a vapor and mixed with air. This is similar to the carburetor on an automobile. The oil is atomized either by steam, air or mechanically. Mechanical atomizers require high pressure oil at 125 pounds per square inch and this is hazardous. Steam or air is usually used, the steam being used in high pressure steam heating systems in 100 horsepower boilers or more. Air atomization from 8 ounces to 2 pounds pressure is most common for the small and medium-sized heating systems. A combination of air and steam may be used. In this case the oil is atomized by air compressed by electric pump until steam is obtained in the boilers, then surplus steam is used for atomization.

In one system the oil is furnished by means of a rotary oil pump which is connected by chain to the shaft of the air blower. The latter operates at 1½ pounds per square inch. As the blower and pump are interconnected any stopping of the blower, which means shutting off of the air, also stops the oil pump. This guards against unatomized oil being pumped into a hot furnace, a cause of many fires in the earlier days of oil burning.

When electric current is available a turbo compressor type of system is most efficient and economical. The oil is supplied in this system by a motor-driven or belt-driven rotary pump. In order to interconnect the air and oil supplies, an automatic cutoff valve is used. If the air pressure fails the oil is automatically and immediately closed. This system is highly efficient and economical; it requires practically no care and is safe.

There are several types of burners or oil guns employed, some throwing a flat flame and others long, soft flames. One burner is about as good as another so far as the quantity of oil consumed. An adjustable type in which the quantity of air and oil can be regulated is desirable. The burners as a rule are not placed in the furnace wall, but about an inch away. These burn through an orifice in the ash pit door or fire box door. In some systems, however, they are cemented in. In others they fire from the rear of the boiler. Extra burners should be provided, so that those being used can be cleaned. Burners must be cleaned once a week with gasoline.

The boilers used need only to have the grates removed and the interior of the fire box lined with fire brick. It is usually found that, due to the greater efficiency of the oil systems, one boiler may be able to perform the work of two. This gives an extra boiler for emergency.

It is likewise probably a good plan to have some coal fuel available and an extra boiler ready in case the electric current which pumps the oil and air fails.

For the small greenhouse range, the automatic oil burning systems such as used for dwellings are satisfactory. These are made up to 4,000 square feet of radiation.

To sum up the proposition of oil as a fuel for greenhouse heating it might be stated that the cost of fuel oil is about the same as coal. In fact the price of oil is determined on this basis. There is a distinct saving in the labor employed and the oil system is more convenient in many ways. The cost of installation or changing over from the coal to oil burning may frighten away a grower, but it is claimed from experience that this cost is made up in a few years.

Any grower using 200 tons of coal or more should consider oil. Below this amount, there is probably not enough saved, although in small installations there is a saving in the carting of coal and removal of ashes.

The prospective user of oil should consider the standing of the company furnishing the equipment, the design and operating characteristics of the equipment and the future service available.

WATER SUPPLY

An unfailing water supply must be provided for the culture of greenhouse crops. Likewise this water must be under sufficient pressure so that plants in different parts of the range may be watered and syringed at the same time.

Where city water, drawn from an open reservoir, is available it is a distinct advantage, for it is usually of sufficient pressure and is cheaper than the cost of home supply. From 25 to 75 pounds pressure should be available, depending on the size of the range. If city water is not obtainable, the water may be pumped from a nearby pond or river. These sources are better than a well, as in the latter case the water is very cold, lacks beneficial chemical constituents and is not well aerated.

When a private water system is used, sufficient storage capacity should be provided to meet the needs of a day or two. While relatively small amounts of water will be used during the winter, an average of about 50 to 60 gallons per 1000 square feet of bench or bed surface will be required per day during June and July. A tank on a tower, a pressure tank in the boiler room or a reservoir on some nearby hill may be used for water storage. The water pressure as well as quantity is determined by the storage tank.

Windmills are quite satisfactory and are the cheapest source of power for small ranges provided there is sufficient storage capacity to make up for times when the wind is low. The geared steel wheel mills will run in light winds and are more efficient than the wooden wheel mills. For a range of any considerable size in order to get sufficient pressure the tank must be elevated considerably, and since a large tank is necessary, this is not practicable; the cost of the supports

would be prohibitive. Pneumatic tanks are better in this case. Water pressure from elevated tanks is, of course, obtained by gravity.

The following table gives the gravity water pressure obtained when tanks are elevated at various heights.

Height in feet	*Pressure per square inch*
10	4.33 pounds
20	8.66 pounds
30	12.99 pounds
40	17.32 pounds
50	21.65 pounds
60	25.98 pounds
70	30.31 pounds
80	34.64 pounds
90	38.97 pounds
100	43.30 pounds
110	47.63 pounds
120	51.96 pounds

In general one of the many types of combination lift and force pumps on the market is commonly used to pump the water into a storage tank, the latter being either elevated and open or of the pneumatic type and placed in the boiler room, or in a separate cellar. The pneumatic storage tank has a distinct advantage in that it may be placed in any out-of-the-way place, provided it will not freeze. It should be provided with a safety valve and pressure gauge. These pumps may be geared to a gas or steam engine or operated by an electric motor. Where steam is used for heating, a small steam pump may be used. When hot water heat is used, either the gasoline engine or electric motor will prove more economical to operate the pump. The steam pump may be used to pump manure water from a manure tank as well as clear water over the range.

A pump of sufficient capacity must be used in order to provide the desired amount of water needed. In general a

one horsepower pump will pump 30 gallons per minute to a height of 100 feet. When a pneumatic tank is used extra power will be required in pumping against pressure. Extra power will also be required when pumping water from a considerable distance. In order to avoid frictional loss in pipe, it is better to use pipe of generous size.

Capacity of Round Storage Tanks

Diameter Feet	*Height Feet*	*Capacity Gallons*
4	4	378
4	5	470
4	6	567
4	8	756
5	3	440
5	4	588
5	5	735
5	6	735
5½	8	1400
6	2	423
6	2½	528
6	3	635
6	4	845
6	5	1056

Capacity of Rectangular Tanks

Width Feet	*Height Feet*	*Length Feet*	*Capacity Gallons*
2½	2½	8	378
3	2	8	360
3	2	10	448
3	2½	8	448
3	2½	10	565
3	3	10	673
4	2	8	478
4	2	10	598
4	2½	8	598
4	2½	10	748
4	3	8	718

About one-third the capacity is occupied by compressed air in the pneumatic tanks.

The greenhouses must be piped so that all parts can be reached with a moderate length of hose. Water faucets or bibbs should be placed in each walk just beneath the bench or alongside the ground bed, and not over 50 feet apart. This allows for the use of a 25-foot hose which is an economical and convenient length to handle. The supply pipes for the watering system should be placed in position before the walks are laid. It is much easier to perform the work at this time. If concrete walks are used, however, the supply pipes should not be placed beneath them. This would necessitate breaking up the concrete in making repairs.

Vegetable growers, and in several instances florists, have found it desirable to install the overhead system of watering. This lessens the time spent in watering the crops and it will be found an economy when used on crops that can stand overhead watering. In this system the water pipe is run overhead lengthwise of the house, supported by the interior posts or other greenhouse supports. These pipes should be about 16 feet apart, can be 500 feet long if necessary, and should be as far from the foliage as possible. Nozzles which throw a fine, rainlike spray are inserted in the pipes 3 feet apart. The pipes may be rotated so as to throw a spray on both sides. This system will work satisfactorily with a water pressure of from 10 to 30 pounds.

CHAPTER X

Frames and Storage Pits—Coldframes—Plant Forcers Heating of Frames

THE term frames includes both hotbeds and coldframes. The former are artificially heated, while the latter are not. Although they are not as easy to care for as greenhouses it will be found that an ample area of frames will increase the area under glass materially and will relieve the congestion which is common in most greenhouses in the spring, especially for the grower of general crops.

Hotbeds serve the same purpose, on a small scale, as a greenhouse, in that seedlings of flowers or vegetables may be started in them in the spring. Coldframes are used more to "harden-off" seedlings and other young plants before being moved from the greenhouse to the garden or field.

Frames should be located in a protected place, receiving protection from a tight board fence or building on the north or northwest. When located between greenhouses they are very well sheltered. This also facilitates the heating of them by the same greenhouse heating system. They should face the south or southeast so the sun will shine on them all day. The land on which they are located must be well drained, sloping southward if possible and a water supply near at hand is desirable.

If horse manure is to be used for heat, a pit must be dug from 10 to 24 inches deep, depending on the amount of manure needed. This will vary according to locality. In cold climates about 15 to 18 inches of packed manure will be necessary, whereas in warmer climates about 6 inches will be ample. It is best to prepare the pit in the fall, plac-

ing in a layer of leaves or manure to prevent hard freezing. Its length will be governed by the number of sash to be used, while the width is ordinarily 6 feet, standard sash being 3x6 feet.

A frame must be erected around the pit. This may be made of wood, concrete, brick or stone. It may be built the entire depth of the pit, or only 4 to 6 inches below ground level. In the former case it aids in keeping out obnoxious ground diggers such as moles and mice. Concrete frames are sometimes preferred as they last longer and need less attention in the way of repairs. An objection may be raised, however, in that it may be desirable to change the location of the hotbeds and with concrete or brick and stone this is not possible. Wooden frames may be taken up and stored when not in use.

Cypress, pine or hemlock planks, 1½ to 2 inches thick, are most commonly used in the construction of the frame. These may be 10 to 12 inches wide and preferably cut so they will be 6, 9 or 12 feet long, to reach supporting stakes which are driven into the ground just under the sash rails across the top of the frame. In building the frame start on the north side, placing the bottom planks, driving the supporting stakes firmly into the ground. These stakes should be 2x3 inches and as long as the depth of the pit plus the height of frame above ground, allowing for an additional foot in the ground. It is well to place these at the corners and 3 feet apart along the sides and ends. Additional planks may be added until the proper height has been reached. Usually the north side is built about 15 inches above ground and the south side 9 inches, giving a slope of 6 inches to the sun. This slope allows for water to run off.

After the north side is built, and the planks are nailed to the stakes, the south side may be built 6 feet away and parallel to it. Then the ends are erected so that the grade from north side to south is met and the sash at the ends will

lie flush. Angle irons should be placed in the corners near the top to prevent spreading. Sash rails are placed across the frames, resting on the tops of the supporting stakes. These may be of 2x3 inch lumber, with or without a lip in the center. The center lip allows the sash to slide better. It is best to make these sash rails removable, otherwise they interfere with the filling of the pit.

Braces of 2x3 inches or 2x4 inches are also desirable, being placed across the pit at the bottom and fastened to the supporting stakes.

Concrete frames are made the same size as wooden ones, with walls 4 or 5 inches thick. Forms must of course be used on the inside and for that portion above ground on both the inside and outside. A mixture of 1 part cement, 2 parts coarse sand and 4 parts of gravel will be good. Old scrap iron bars may be placed in rows 6 inches apart all around the frame as the concrete is poured and tamped in. This extra reinforcing is desirable. The frames should extend below the frost line. Care must be taken to see that the concrete does not work out from under the bottom of the forms and so interfere with drainage. Wooden sash rails are commonly used across the tops, grooves being made to allow for their easy placing and removing. In order to make these grooves, wooden blocks, which have been greased, are inserted in the wet concrete. When the concrete is dry these blocks will readily come out due to the grease on them. If not greased, the corners will break off leaving irregular grooves.

Some little surfacing with 1 part cement and 1 part sand mixture may be found necessary here and there on the concrete frame, after the forms have been removed and the concrete is dry.

The top of the concrete frames may be capped with a cast iron sill plate similar to the capping of the side wall in a greenhouse. This adds considerably to the life of the

concrete but also adds a good deal to the first cost of construction.

Brick or stone frames may be found more commonly built on private estates. These are just as satisfactory as the concrete ones but will probably prove more expensive due to the greater amount of labor involved.

Banking the outside of the frames with manure, leaves or soil helps to hold in the heat and prevents washing of the soil around the frames.

Greenhouse manufacturers make standard hotbed and coldframe frames in sizes for one or more sashes. The depth of the frame is 8 inches in front and 16 inches at the back, it is made of 1¼ inch thick cypress. The corners are bolted with cast iron cleats. In this case a sub-frame should be built first and then these frames set on top.

Temporary frames are occasionally used when it is not desired to dig out a pit. In this case the frame and sash are set on a 2-foot layer of manure, the latter being spread out on the ground, about a foot wider on all sides of the frame. This is wasteful of manure but eliminates the need of a pit or sub-frame.

SASH

The sash should be made of a durable wood, either cypress or cedar. Standard hotbed sash are 3x6 feet and from 1⅜ to 1⅞ inches thick. The sash must be able to stand rough usage and so must be well constructed, well painted and made of good material. They may be obtained from any reliable greenhouse dealer. A light iron bar across the middle of the sash, connecting the side bars prevents the sides from spreading. Most sash consist of three rows of glass, using 18 panes of 10x12 inch size. Many are made of four rows, or 28 panes of 8x10 inch size, but the extra lap and necessary sash bar obstruct too much light. The sash may be purchased unglazed and unpainted, or glazed and

painted. A considerable saving can be made by glazing and painting at home.

The glass is laid either butted or lapped. When lapping, beginning at bottom of sash, one pane is laid over another, allowing ⅛ inch lap. When the glass is butted, the panes are simply laid end to end. This method of glazing is not as good because the panes are often not squarely cut and do not fit well, and the sash have so little pitch or slant when in use that water is apt to run between the panes and on the plants in the hotbed. The glass should be puttied similarly to greenhouse roofs.

Double-glass sash, made of two layers of glass with an air space of about ½ inch between, are sometimes used. They have certain advantages and disadvantages. They give greater protection and reduce labor, as it is not necessary to use mats so late in the season. However, because of the disadvantages their use is not generally recommended. Their first cost is almost 50 per cent greater than that of ordinary single glass sash, they are heavier to handle, they reduce the amount of light when dust settles between the layers, and lastly, they are shorter lived, as moisture settles between the layers of glass and causes rapid decay.

MATS AND SHUTTERS

Some sort of supplementary covering is needed on hotbeds and coldframes in cold weather. This is especially true when single, light sash are used.

Rye straw mats are used extensively. They can easily be made at home by hand, using home-grown rye straw, but machine-made ones can be reasonably purchased. They are generally made 6x6 feet or 6x7 feet so as to cover two sash and give some overlap. An objection to straw mats is their weight, especially when wet. Also, mice sometimes harbor in them when stored. These mats will last from three to four years. Burlap or canvas mats are good. They

are padded with waste cotton and are durable and warm. Old carpets, quilts or horse blankets may be used, as well as hay or straw to give this added protection. Mats should be thoroughly dried before storing.

Wooden shutters 3x6 feet made of ½ inch lumber are sometimes used over mats in stormy weather. They facilitate removing snow from the sash and also aid in keeping in the heat. When hotbeds are started very early in the season, they are useful, but for hotbeds started early in April, they are not necessary.

Slats 3x6 feet, consisting of ¾ inch wide and ¼ inch thick cypress, with cross binders ⅞ inch square, will be found useful for shading plants in the frames during summer. Spaces are left the width of the slats for light and air. These slats may be made of ordinary building laths, covering the cross strips with laths next to each other, and then nailing every other one. This is a quick way of spacing the slats.

COLDFRAMES

The coldframe resembles a hotbed but differs in having no deep pit or any means of artificial heating. The sun is the only source of heat used to force the plants. The frame is set directly on the ground.

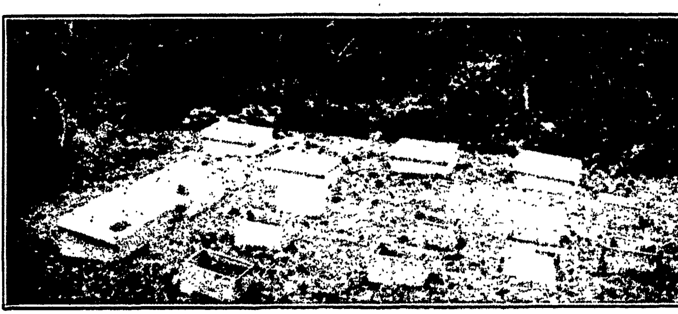
Coldframes are used later in the season than hotbeds for hardening the plants which were started in the hotbed. "Hardy, cool plants," such as cabbage and lettuce may be grown to maturity in them, started either in early spring or late fall and wintered over. "Warm plants," such as cucumbers, melons, etc., are sometimes started in them about May 1st, and when the frost is over, the boards and sash are removed and the plants given use of the entire ground. They are also useful for the fall storage of Dutch bulbs and the wintering over of pansies and violets.

The location and arrangement for coldframes are the same as for hotbeds. They should be situated on a rich, well drained, sandy loam.

The height of the sides must be determined by the height of plants to be grown. Ordinarily 12 inches is high enough for the north side and 6 inches for the south side. The frames may be movable or stationary, made of wood or concrete. The size of the frames, sash, sash bars, etc., and their construction are the same as for hotbeds. The coldframes should be ventilated the same as the hotbed. When used in cold weather, the outside of the frames should be banked with soil, manure or sod.

PLANT FORCERS

Plant forcers are used for protecting both heat-loving plants and cool plants. They protect against light frosts and some of them guard against insects as well. When



Plant forcers in use

warm weather comes, they are removed entirely. These forcers are often used in connection with crops that must be seeded in place in the field. They are not good for large areas as they require too much time in tending them, being scattered over much territory. However, for the small

home garden they often prove useful, acting as small cold-frames for the individual plants.

One of the most common types consists of a wooden box about 6 inches deep and 10x12 inches or 12x14 inches, covered with a pane of glass. The plants such as melons and cucumbers may be set directly out in the field and by using one of these boxes over each plant, they are protected. Wire screen is sometimes used over the top when the glass is removed to act as an insect protector.

FRAMES HEATED BY HOT WATER OR STEAM

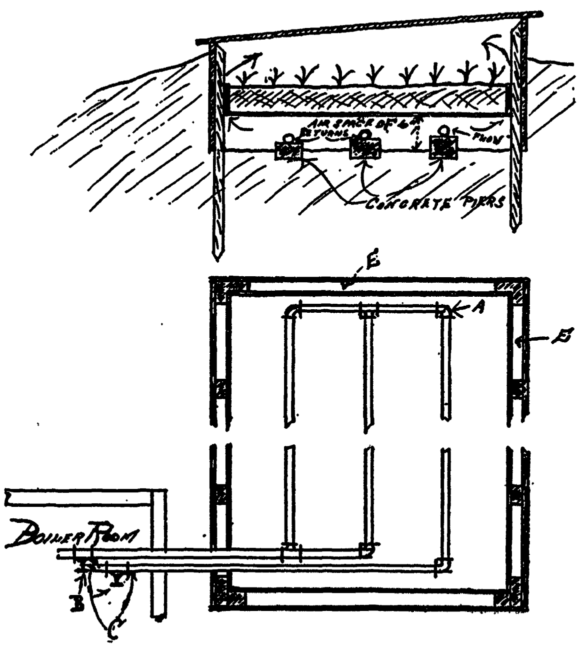
In these times of shortage of manure hot water heating of the hotbed has become increasingly common. The same heating apparatus for the greenhouse or home may be used to heat the frames, with pipes running around the inside of the frames or underneath the soil. This provides the necessary heat without the bother of making hotbeds each spring.

The following article by Frank J. Moreau of the Moreau Plant Company, Freehold, New Jersey, explains the construction and operation of a practical hot water heated frame.

"The accompanying sketch shows a pipe-heated frame used by us, which has proved successful in every way. In these times of shortage in fuel, which threatens to reduce greenhouse space, and shortage of manure, which has consequently such increased value as a source of fertilizer that it is too expensive to use as a means of heat, the following proposition is one which might be of use to anyone who finds his greenhouse space somewhat congested at different seasons.

"This idea suggested itself to us because of the necessity of having a steadier source of heat than manure and one which could be regulated. The system of heat used by us is hot water, pipe lines consisting of one flow and two

return 2 inch pipe being used throughout. During the spring months many greenhouses do not carry all the coils necessary for winter use. These being cut off with us, we turn this surplus radiation into the frames and find that it takes very little increase in fuel to operate. In fact it cost \$1.50 less per sash to operate than a frame of the same size heated by manure. The system is so arranged that heat can be cut off from the boiler room and the water drained from the system by means of drainage cocks placed at C. At point A the elbow is tapped and connected with a ⅜ inch pipe leading through the soil to a pet cock which can readily be reached by opening a very small aperture in the covering.



Hotbed heated by hot water

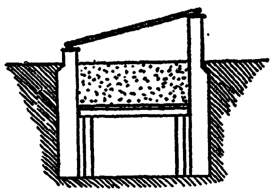
"We use single light sash with mats on very severe nights. The spaces at E show an air space 2 inches wide running the entire length of the frame. The soil bench is constructed the same as an ordinary greenhouse bench, being built to hold about 6 inches of soil. Running the length of the bed is a joist which takes the weight through the middle, otherwise the bench would sag and water would drain to the middle of the bench.

"Under the soil bench is an air space of 6 inches through which the coils are run instead of being buried in the soil, a practice which to our mind, causes the loss of much heat. Thus you see the plants are growing in a bench of soil which does not come into direct contact with the cold earth outside, making it possible to maintain an even soil temperature night and day.

"With the ground frozen outside for days at a time we have been able to keep a soil temperature of 60 degrees and a temperature above of 58 degrees to 60 degrees at night. The past season we operated one frame 80 feet long, sown with peppers and eggplants and had a better stand than we have ever had before in our experience. After these plants had reached a height of about 2 inches we experienced a week or rather five days, of continual sleet, which froze as fast as it fell, making it impossible to ventilate or even open the frames to the light. In the pipe-heated frame there was about 2 feet of row that damped off while out of the other frames we lost as much as 50 per cent of the plants; this was due to the fact that in the pipe-heated frame the dry heat from the pipes kept the surplus condensation dried up, while in the other frames the lack of heat caused the loss of thousands of plants. We operate in our plant season about 10,000 feet of frames, growing vegetable plants exclusively, and the plan just given has eliminated many troubles to be found in the plant growing business."

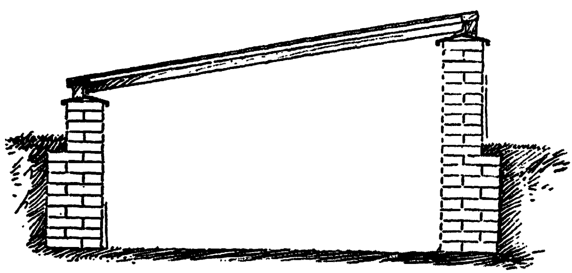
STORAGE PITS

Pits are used for the storage of plants that need protection from the frost to carry them through the winter i. e., hydrangeas, boxwoods, baytrees. They are excellent for bulb storage such as hyacinths, tulips and narcissus, until well rooted.



Converting pit into coldframe by building platform

They are simply pits 4 to 6 feet deep, made of concrete, stone or brick, extending above ground like a hotbed and covered with sash, shutters or boards. A platform may be built in it in the spring, making a false bottom and it can then be used as a hotbed or coldframe. These pits must be located in a well drained location.



Storage pit made of brick with cast iron sill capping walls and cypress frame

CHAPTER XI

Glass Structures for Amateurs—Conservatories

THE benefits which an amateur gardener will derive from a small greenhouse are numerous. Such a house will prove a source of endless pleasure and not add very much in the way of extra labor.

In the first place, many pleasant hours can be spent among the plants during the cold winter months. This will help greatly to relieve nerve tension and make life the more worth while. Cut flowers and attractive plants may be had all year round to help beautify the home. What a joy it would be to give flowers of your own raising to a sick friend, or remember somebody's birthday with calendulas or a primrose from your own greenhouse and grown by your own efforts! These flowers will be more beautiful to you because of the personal contact with them.

A small greenhouse would enable one to have a collection of choice tropical and rare plants, which would be difficult to grow in the home. In fact very few homes have situations favorable to growing house plants and with the possession of a small greenhouse cultural conditions would be more ideal. The temperature, water and light conditions are better and insect pests and diseases are more readily controlled in a greenhouse. Plants could be grown to perfection there and then used to beautify the home.

The gardener could dispense with hotbeds for the raising of flower and vegetable plants for his garden in the spring. Thus a great amount of annual labor and expense would be eliminated. These plants are much more readily cared for in a greenhouse, because of the protection afforded the at-

Attached Lean-to Greenhouse Planned by the Architect as a Part of the Home

tendant from bad weather and the elimination of so much "stooping over." The quality of the plants would thus be improved, as they would receive the attention necessary. This would have a beneficial effect on the vegetable and flower garden in the summer.

There would be a saving in the losses usually experienced by amateurs in the carrying over of tender plants from outdoors, during winter. Cannas and dahlias may be stored under the benches and boxwood trees, oleanders, etc., could be stored in a safe place from one season to another.

Many plants could be more readily propagated with ease in a greenhouse than elsewhere. Old bedding plants, such as geraniums, coleus, heliotrope, etc., may be carried over winter and cuttings taken from them in the spring to have nice thrifty plants for the window boxes and garden each year.

The amateur starting with a small house and gaining experience in greenhouse management from it may eventually find himself well adapted to this kind of work. Such a start may be the beginning of a thriving business. Many successful florists of today were the amateur gardeners of several years ago.

A small greenhouse adds distinction to a home and makes it so much more valuable. Such small glass structures usually are built as a lean-to or even span against the south side of the house. They may have the regular commercial angle eave without a gutter or may be more elaborately built with a curved eave, curved glass at the eave and with a gutter.

The lean-to house is the simplest and cheapest to erect. It can be built up to 15 feet in width. Beyond this it is best to build even span houses.

The houses may be of the so-called all wood, half-iron or full iron frame construction. In general principles such structures follow the same rules laid down for commercial

construction, but on a small scale. The greenhouse roof next to the dwelling should be boarded for 3 or 4 feet and heavy wire screening placed 4 inches above it, so that ice from the eave of dwelling will not fall on the glass.

The beauty of a small greenhouse is that it can be built to suit an amateur's purse, from a few hundred dollars up. The price will fluctuate with the size and elaborations. Many can be readily erected by the novice. Materials are best obtained from a greenhouse manufacturing concern. These come all cut to fit and can be erected with the ordinary household carpenter tools. Blue prints, directions and advice in erection is furnished with the materials.

Ordinary hotbed sash may be used in the sides, ends and roof, for a cheap homemade glass house. These sash must be supported by a framework of 2x4 inch studs. With the assistance of a carpenter such a structure can be readily built.

As for the winter heat of these small structures, this could be supplied from the hot water or steam boiler in the dwelling house. A great saving is thus made, as only some extra heating coils need be purchased. A house 6x12 feet or 8x10 feet or thereabouts could be taken care of readily by the average dwelling boiler. In some cases an extra section or two may have to be added to the boiler to provide the necessary heating radiation. The small automatic oil burners, with thermostatic control, so commonly used for heating dwellings today, make it possible to maintain an even temperature in the greenhouse no matter what the temperature is outdoors. With this system the extra care and annoyance of firing during extremely cold periods will be eliminated. A thermostatic control is desirable to insure a uniform temperature even when coal is used as a fuel.

There are several architects today who, when planning for their clients, advocate the building of a small conservatory or greenhouse attached to the dwelling as a

definite unit. If such is the case the heating requirements of both the house and greenhouse can be figured in at the start.

Several builders make a specialty of supplying portable greenhouses in certain standard sizes and units, which are bolted together, and built on foundations locally made. They can be attached to the dwelling or any other structure, as desired. The ease with which such houses can be built recommends them very highly to the amateur.

In recent years many greenhouse-garage combinations have been built. It may not be possible or desirable in some cases to have the greenhouse attached to the dwelling. The garage then provides an excellent structure on which to build. The boiler can then provide heat for the garage as well as for the greenhouse. In the ordinary home garage where no great amount of repair work is done, no damage results to the plants from any smoke or fumes from the automobile.

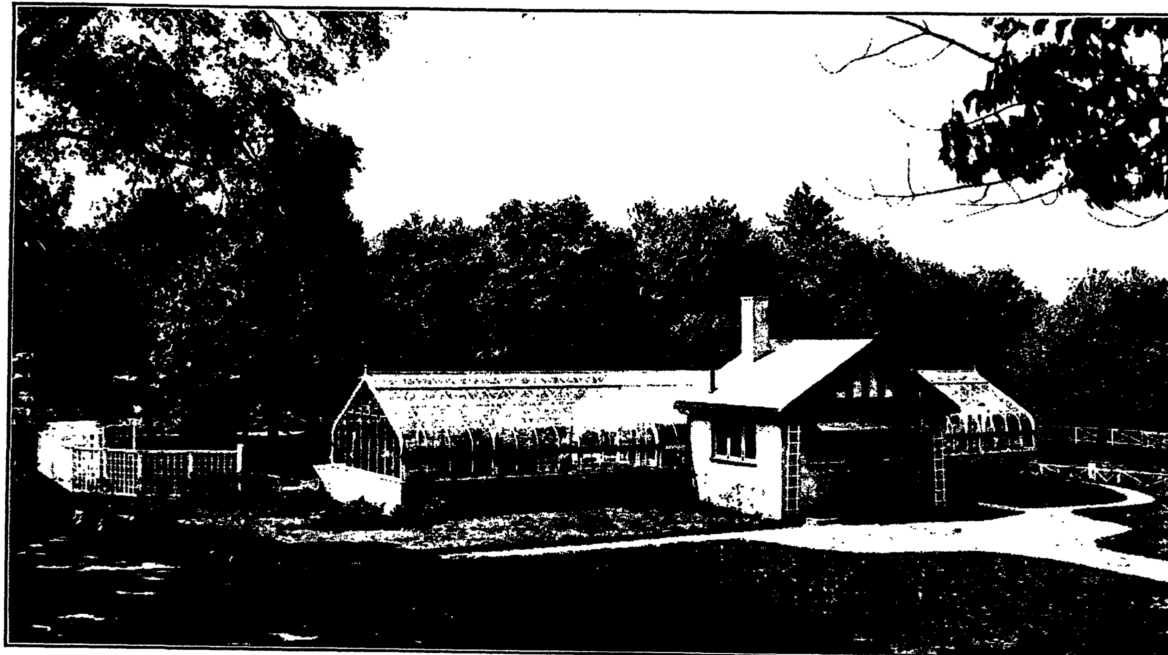
In case a separate heating system must be provided, then the greenhouse built should be large enough to warrant the expense.

Larger houses are usually built with a small workhouse at one end, in the cellar of which the boiler is placed.

In conclusion, it might be mentioned that these small greenhouses may be purchased on a budget plan, in the same manner that pianos, automobiles, and various articles may be purchased these days. Buying it this way makes its payment possible out of the regular income.

CONSERVATORIES

A conservatory is in reality a show house in which plants are placed for display. These plants are generally grown to maturity or perfection in ordinary greenhouses attached to the show house.



Private Estate Conservatory

There are various types of conservatories, the simplest being the small amateur one, attached to the residence and heated by same or separate heating system. Then there is the conservatory of the commercial grower who displays the plants he has for sale in it. The retailer may also have a small conservatory attached to his store, this being often constructed on the roof or in the rear of the building in which his store is located.

The most elaborate conservatories are found in public botanical gardens, and here many palms and rare tropical plants are housed. The conservatories found on private estates and cemeteries are similar to those just mentioned but are generally on a smaller scale.

As regards the construction of conservatories, they must be pleasing architecturally, a consideration not called for in commercial houses. Thus the location is carefully selected where it will have a good setting. Then curved lines and good architectural details are added to help beautify the structure. Generally curved eaves, curvilinear and domed or lantern roofs are built. High eaves and roofs are essential to house properly the tall growing palms and other tropical plants. Ground or frosted glass is used in the roof to shade the plants. Gutters are generally placed at the eave or sill plate not only to conduct the water off the roof, but to give a strong architectural line.

In the interior arrangement, plant tables are used at the sides rather than benches, these tables having tile or slate bottoms, on which pebbles or crushed stone are placed upon which to rest the pot plants.

The center of the house is often kept open and at the ground level or nearly so, a concrete curbing built to hold the soil. Specimen plants of the tall growing kinds are here planted out or else grown in large pots and tubs and set on gravel in this area.

The walks in these show houses must be wider than in the ordinary commercial house, because of the greater amount of traffic in the form of visitors who will use them. From 3 to 5 feet will be found desirable as against 2 feet to 30 inches for the commercial house. Brick, tile and concrete are generally used to give a cleaner and more permanent type of walk.

Pools with aquatic plants, rockeries and grottos with ferns are some extra features often introduced.

Stages, or series of shelves on the plant tables, may be employed to display the pot plants in a better manner.

In the heating system of conservatories, hot water is generally preferred, the pipes being placed as inconspicuously as possible, often on side walls and below walks hidden by iron gratings. Ventilators are generally placed at the ridge and panel ventilators in the masonry side walls.

INDEX